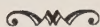


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71. John Van Oosten	1941-1942	St. Louis, Mo.
72. John Van Oosten	1942-1943	(No meeting) ²
73. John Van Oosten	1943-1944	(No meeting) ³
74. John Van Oosten	1944-1945	(No meeting) ³
75. John Van Oosten	1945-1946	(No meeting) ³
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84. A. L. Pritchard	1954-1955	Seattle, Wash.

² The annual meeting scheduled to be held in New Orleans, La., was cancelled because of the war emergency.

³ No annual meeting scheduled because of the war.

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Part 1
Papers

THE EFFECTS OF TEMPERATURE AND PREDATORS ON THE ABUNDANCE OF THE SOFT-SHELL CLAM, *MYA ARENARIA*, IN NEW ENGLAND

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ABSTRACT

Explanation of the recent decrease in production of the soft-shell clam in New England is the objective of the Fish and Wildlife Service Clam Investigations. Experimental clam farms failed unless protected from green crabs, *Carcinides maenas*. Laboratory experiments proved that *Carcinides* is a serious predator.

Clam abundance decreased 50 percent in 4 years in study areas even though fishing intensity was very low and reproduction was adequate. Population decrease occurred principally in places where green crabs had become abundant, and in size groups which are attacked by crabs. Clam population on commercial flats decreased from 1949 to 1954 and recent year classes are scarce or absent. Green crabs became abundant during this period.

Scientific records and interviews of fishermen indicate a northeastward extension of the range of the green crab since 1940 and great increase in abundance in Massachusetts, New Hampshire, and Maine. This extension was accompanied by decrease in clam production.

An increase in the abundance of green crab in the northern part of its present range is correlated with the current warm cycle. Winter temperatures are important to survival of green crabs since they and their eggs are reported to be killed by a combination of low temperature and low salinity. Warm winters allow more crabs to survive. Predation was accepted as the principal reason for the decrease in soft clams in Massachusetts and Maine. The future of the soft clam industry depends on the temperature cycle or on development of measures for controlling green crabs.

INTRODUCTION

Commercial production of the soft-shell clam in Massachusetts decreased from 8,598,100 pounds in 1940 to 625,000 in 1948. The output remained high in the State of Maine during this period but the industry and the Maine Department of Sea and Shore Fisheries became alarmed over the possibility that a similar decrease might occur in this State. The Fish and Wildlife Service was authorized by Congress in 1948 to determine the reasons for the decrease of soft-shell clams and to recommend measures for restoring production to a higher level.

Since 1948 Massachusetts clam production has remained at a low level. The slight increase during 1950 to 1952 (Fig. 1) was caused by marketing of clams from Boston Harbor after they had been cleansed to reduce coliform counts.

Maine's production decreased steadily from 8,969,000 pounds in 1948

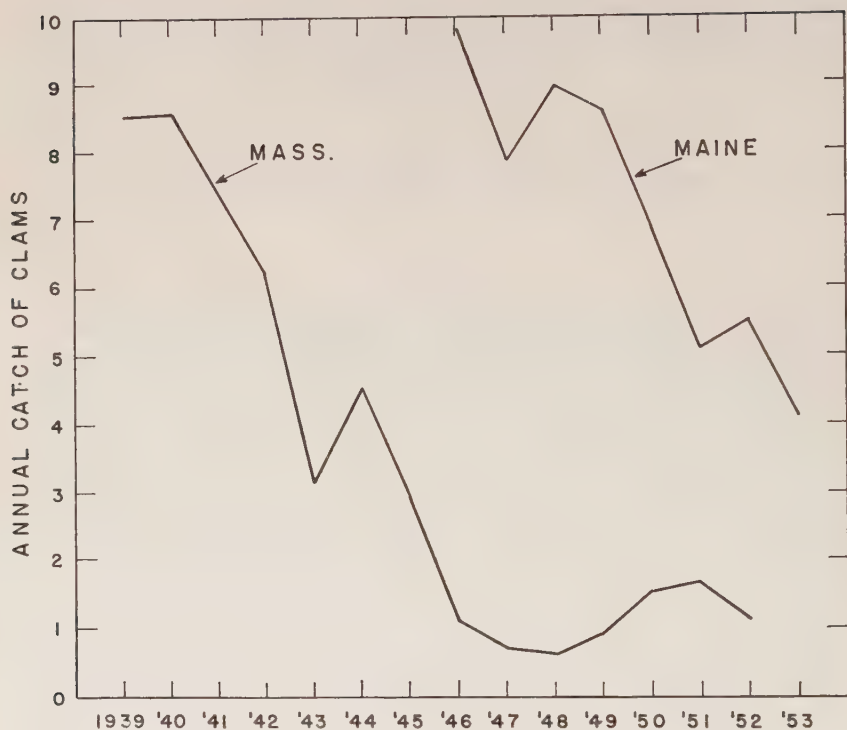


FIGURE 1.—Annual catch (millions of pounds of meats) of soft-shell clams in Massachusetts and Maine during the recent decline. Source: Fishery Statistics of the United States, (Anderson and Peterson 1953 and 1954)

to 4,148,000 pounds in 1953. This decline was alarmingly similar to that which occurred in Massachusetts about 8 years earlier.

Overfishing was generally believed to be the cause of the clam scarcity when our investigations began in 1948. Prices were high, market demand was heavy, and the fishery was intensive. If overfishing were truly the cause, two approaches were indicated: first, development of methods of farming clams similar to those used with oysters; and second, productivity studies to determine how many clams could be harvested each year without causing depletion.

EXPERIMENTAL CLAM FARMS

Clam farming was the first method which we tried for increasing production. We found an excellent source of small clams at Scarborough, Maine, and developed a hydraulic seed clam rake which would remove these clams from the sand so that they could be transplanted.

During 1950 and 1951 we planted seed clams in five places in Maine.

All of these farms failed except that in Sagadahoc Bay. Each failure could be directly traced to predation by the green crab, *Carcinides maenas*. The farms at Southport and Spurwink River lasted only 3 weeks. At Jonesport some clams survived for 2 or 3 months. At Wells most of the clams were eaten by crabs during the first 6 months.

The abundance of green crabs in the center of Sagadahoc Bay was very low during this period and the success of this farm could be attributed to their scarcity. Since that time the green crab abundance in Sagadahoc Bay has gradually increased so that we would not expect the same degree of success in clam plantings at the present time. The crab population at Wells was low at the time we planted the clams but increased immediately afterwards. Succeeding plantings by the Maine Department of Sea and Shore Fisheries 2 months later were consumed in a few weeks. Our plantings survived up to 6 months because the clams had a chance to become established and grow before the green crabs invaded this area.

Later farms were protected from predators and the clams survived and grew well. Some plantings were covered with 1-inch-mesh chicken wire laid directly on the flats. This protection excluded the green crabs, but was exceedingly expensive. Recently our biologists have developed a low chicken-wire fence (Smith, 1953) which excludes green crabs and which costs less per unit area than covering with screen. The clam farms demonstrated the importance of predators. Soft clam farming can only be recommended as a method of increasing production if predation by green crabs can be controlled.

SAGADAHOC BAY PRODUCTIVITY STUDIES

In 1949 we chose Sagadahoc Bay on Georgetown Island, Maine, as a study area to determine the relationship between commercial fishing and abundance of clams and to develop methods for establishing an optimum fishing level. Each year since that time we have conducted a population census of the clams in this Bay. We have also obtained catch records from the commercial fishery. Fishing intensity has remained low during all of this period; in fact, during 1951 and 1952 the fishing effort was negligible since most of the diggers were employed at Bath Iron Works building destroyers. Since that time many diggers have returned to the flats but their production has remained low.

We feel that setting has been adequate each year. Early each spring we found a good population of clams—10 to 100 per square foot—from the spawning of the previous summer. By autumn practically all of these small clams had disappeared. In places where the green crabs have been excluded by fencing or screening, survival and growth have been excellent. We accordingly believe that green crabs are responsible for the disappearance of the young clams. In laboratory experiments medium-sized green crabs consumed up to 15 small *Mya* per crab per day. Therefore, a moderate population of crabs could consume an entire year class of small clams in a short time.

The population of clams over 25 millimeters long in Sagadahoc Bay has decreased from 40 million to 18 million during the period from 1949 to 1953 even though the commercial fishery has remained at a very low level. Most of this decrease has been in the illegal-sized clams, from 26 to 50 millimeters in length. The principal decrease occurred in areas A and B (Fig. 2) near the shore of Sagadahoc Bay. The population in area C, which is in the center of the Bay, has remained nearly constant.

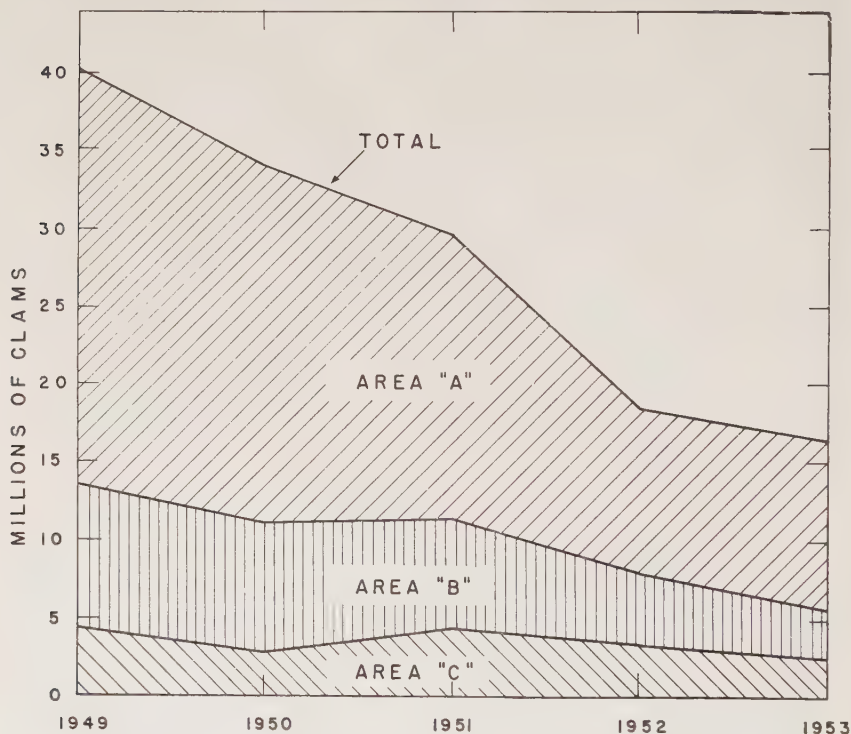


FIGURE 2.—Estimated population of clams over 25 millimeters long in different areas of Sagadahoc Bay, Maine, 1949–1953.

The crab population of Sagadahoc Bay has increased greatly since 1949, particularly near shore in areas A and B. Green crabs require a hiding place at low tide and, therefore, the areas around the edge of the Bay are more suitable than the broad sandy bottom in the center. We believe, therefore, that the decrease in abundance of small clams in areas A and B is correlated with the increase in the number of green crabs in those areas.

CLAM POPULATION SURVEYS

Biologists of Maine Department of Sea and Shore Fisheries sampled representative flats in eastern Maine to determine the size composition of

clams and related species during 1949 to 1951. In the spring of 1954 State and Federal biologists resurveyed several of these flats with discouraging results as shown in Table 1.

Clam populations were lower in most areas surveyed in 1954 than they were at the first surveys in 1949 or 1950. Green crabs were present in 1954 on flats where they were not found in the original surveys. Clams from the 1950, 1951, and 1952 sets were extremely scarce or absent in many areas. When these areas were surveyed in the spring of 1954 some of the 1953 set were still present but these clams were so small that they may have been missed by green crabs. By next autumn these clams also may have been eaten.

The future of the clam fishery in eastern Maine appears to be very dark. Only in Holmes Bay and in part of Randall Point flats did we find a good size distribution of clams. In these broad flats the green crabs have few places to hide at low tide. Some crawl under the rockweed high on the beach during ebb tide and move out in search of food when the tide covers the flats. Other crabs move offshore with the ebb tide and return with the flood. Between these two bands is an area where predation is less severe. Therefore, green crab predation is serious only on small parts of the Randall Point and Holmes Bay flats.

Great Bar at Jonesport maintains a moderate clam population because of the gravel which gives the clams protection from their enemies. Even here the 1953 year class was extremely low and it is likely that many of this group were consumed by the hordes of small crabs.

GREEN CRAB ABUNDANCE

Predation by green crabs must have become more serious during recent years if this is the cause of the present scarcity of clams. Two possible factors which might have increased the importance of predation are 1) a northward extension of the range of green crabs and 2) an increase in their numbers.

Green crabs are temperate water crustaceans which apparently are moving northward in response to the current warming trend cycle (Fig. 3). Sidney I. Smith (1874 and 1879) reported that the green crab occurred only south of Cape Cod. By the early 1900's it was present in Casco Bay, Maine, as reported by Rathbun (1905). Rathbun (1930) gave the range as Thomaston, Maine, to New Jersey. In 1930, two lots of green crabs were collected at Brooklin, Maine. Scattergood (1952) reported green crabs at Winter Harbor, Maine, in 1939, but none northeastward of this location as late as 1942. By 1950, green crabs were seen at Great Bar, Jonesport, Maine, by biologists of the Maine Department of Sea and Shore Fisheries.¹ U. S. Fish and Wildlife Service biologists found crabs at Cummings Beach at Jonesport, Maine, in 1951 when planting an experimental clam farm. Scattergood found one specimen at Carrying Place Cove, Lubec, in June 1951, establishing a northeastern record. Shortly thereafter

¹ Information from Louis Taxiarchis of the Maine Department of Sea and Shore Fisheries, Augusta, Maine.

TABLE 1.—*Summary of clam population surveys in Maine conducted by the Maine Department of Sea and Shore Fisheries and the U. S. Fish and Wildlife Service*

Area	Date of survey	Clams per square foot		Size distribution	Green crabs	Remarks
		Over 1 year old	1 year old			
Calton Point Jonesboro, Maine	1949	10.5	(see remarks)	Good — each year class present	None	Population including spat and clams up to 1½ inches was 75 per square foot
	1954	2.2	7.5	1952 set — none 1951 do. — do. 1950 do. — scarce 1949 do. — common	Very abundant	
	1949	10.5	(see remarks)	Good — each year class present	None	Many small clams near high tide line
	1954	4.0	1.9	1952 set — scarce 1951 do. — do. 1950 do. — common 1949 do. — abundant	Abundant	
Randall Point Machiasport, Maine	1949	5.7	?	Good — each year class present	None	
	1954	4.1	14.9	1952 set — none 1951 do. — scarce 1950 do. — do.	Abundant (see remarks)	Excluding middle of flats where crab predation is less severe
	1949	6.8	Scarce	Most over 2 inches but each year class present	None	
Holmes Bay Machiasport, Maine	1954	4.2	6.3	1952 set — none 1951 do. — scarce 1950 do. — common 1949 do. — abundant	Common	Predation moderate; area unsuitable for large crab population

Area	Date of survey	Clams per square foot		Size distribution	Green crabs	Remarks
		Over 1 year old	1 year old			
Great Bar Jonesport, Maine	1950	5.9	?	Good — each year class present	Abundant (see remarks)	All crabs less than $\frac{1}{2}$ inch in width
	1953	7.1	2.1 (see remarks)	Good — each year class present	Abundant	Spat count includes some 1953 set. Crab predation low because of gravel
	1954	8.6	None	Mostly larger clams but each year class present	Very abundant (see remarks)	Many very large green crabs, but predation low because of gravel
Sam's Cove Bremen, Maine	1949	15.2 to 41.6	Extremely abundant	Excellent population of each year class	None	Population so high that experiment set up to determine if thinning would improve growth
	1954	None	2.3	No clams over 10 millimeters present except in thatch grass	Extremely abundant	Good size distribution of clams in thatch grass and gravel where they are safe from crabs
Cummings Beach Jonesport, Maine	1941	....	....	.....	None	Experimental clam farms successful
	1951	?	?	Each year class present but most of legal size removed by diggers	Common	Experimental clam farm established in April; destroyed by crabs during summer. Digging prohibited
	1954	2.3	5.0	1952 set — none 1951 do. — do. 1950 do. — scarce 1949 do. — common	Extremely abundant	Digging permitted, but few small clams present. Crabs nearly as abundant as in Massachusetts

in July and September 1951 Canadian biologists found green crabs at Oven Head, Digdeguash at Passamaquoddy Bay. This locality was the northeastern end of the range as reported by Scattergood (1952). During 1953, Canadian biologists observed green crabs on the north shore of the Bay of Fundy as far east as Point Lepreau, on the south shore at Pereau River in Minas Basin, and at Sandy Cove in St. Mary Bay, Nova Scotia. The northeastern range was extended farther in August 1954 by the discovery of one specimen at Wedgeport, Nova Scotia.²

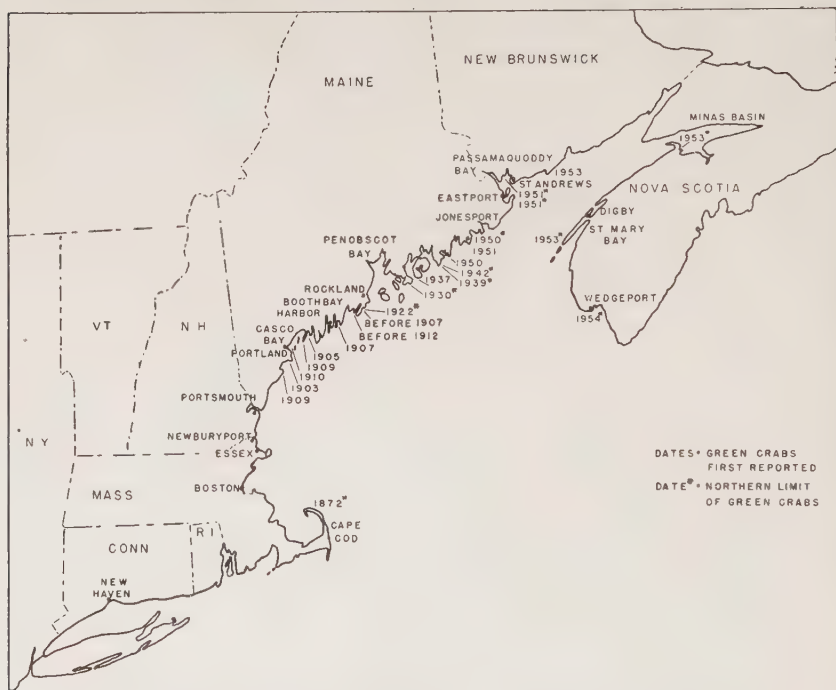


FIGURE 3.—Map of New England showing dates when green crab, *Carcinides maenas*, was first reported. Dates marked with asterisk indicate northern limit of green crabs at that time.

Scientific observations listed above are corroborated by statements from diggers and lobster fishermen along the Maine Coast. During January and February 1952 wardens of the Maine Department of Sea and Shore Fisheries questioned over 100 clam diggers and lobster fishermen. Each man was asked when he had first seen green crabs, or had first caught them in his traps. On the basis of their replies (Table 2), Maine can be divided

² Information from J. S. MacPhail of the Fisheries Research Board of Canada, St. Andrews, New Brunswick.

into two areas: (1) West of Penobscot Bay where the green crabs have been present for as long as living man can remember, *i.e.*, about 1900 to 1915; (2) East of Penobscot Bay where green crabs have been seen only during the last 2 to 10 years, except for one questionable observation in 1919. Some areas existed at the time of this survey where fishermen had not yet found green crabs.

TABLE 2.—*Summary of replies to Maine Department of Sea and Shore Fisheries questionnaire indicating when green crabs were first seen in Maine*

Year	Entire State	West of Penobscot Bay	East of Penobscot Bay	Year	Entire State	West of Penobscot Bay	East of Penobscot Bay
1951.....	5	..	5	1919.....	1	..	1
1950.....	9	..	9	1915.....	2	2	..
1949.....	7	1	6	1914.....	1	1	..
1948.....	6	1	5	1913.....	1	1	..
1947.....	3	3	..	1912.....	3	3	..
1946.....	2	1	1	1911.....	1	1	..
1945.....	3	2	1	1910.....	1	1	..
1943.....	1	1	..	1909.....	1	1	..
1942.....	4	1	3	1907.....	3	3	..
1938.....	3	1	2	1903.....	1	1	..
1933.....	1	1	..	1900.....	1	1	..
1932.....	2	2	..	Total replies.	64	31	33
1927.....	2	2	..				

Question No. 2 of the Sea and Shore Fisheries questionnaire circulated by the wardens in 1952 asked, "When in the past were green crabs plentiful in Maine?" The replies (Table 3) indicate no well-defined break at Penobscot Bay as was found for dates when green crabs were first reported by the fishermen. In all areas most reports indicated crabs were more plentiful in 1951 than at any earlier time. Division of replies into areas East and West of Penobscot Bay suggests that crabs have been plentiful

TABLE 3.—*Summary of replies to Maine Department of Sea and Shore Fisheries questionnaire indicating when green crabs were most plentiful in Maine*

Year	Entire State	West of Penobscot Bay	East of Penobscot Bay	Year	Entire State	West of Penobscot Bay	East of Penobscot Bay
1951.....	45	22	23	1938.....	2	2	..
1950.....	20	9	11	1937.....	2	2	..
1949.....	13	9	4	1936.....	2	2	..
1948.....	9	7	2	1935.....	2	2	..
1947.....	6	6	..	1934.....	2	2	..
1946.....	6	6	..	1932.....	2	2	..
1945.....	5	5	..	1931.....	1	1	..
1944.....	4	4	..	1930.....	1	1	..
1943.....	4	4	..	1929.....	1	1	..
1942.....	4	3	1	1928.....	1	1	..
1941.....	2	2	..	1927.....	1	1	..
1940.....	2	2	..	1926.....	1	1	..
1939.....	2	2	..	Total replies.	140	99	41

in places in the western part of the State since 1934, but not generally so until 1949 to 1951. East of Penobscot Bay crabs have been plentiful only since 1948, except for one record of 1942 at Tremont. These replies agree with the answers to Question No. 1 in indicating that green crabs have been present for many years west of Penobscot Bay and have merely increased in abundance since about 1948. East of Penobscot Bay the absence of early observations of great abundance of green crabs may indicate that the crabs have only recently spread into that area.

The best record of changes in green crab abundance that we have found are those of Franklyn Goucher who, for a number of years, was Clam Commissioner for the Town of Essex, Massachusetts.³ Mr. Goucher described the abundance of green crabs and clams at Essex, Massachusetts, for the period from about 1924 to 1951. He stated that he first saw green crabs there in 1926 and that they became more numerous each year into the early 1930's. Clamming became poorer during this period, and by 1931 no diggers remained. The coldest winter on record, 1933-34, killed the crabs according to Goucher, and from that time until 1944 few were seen. Clamming was good during this period; in fact, records show the peak of production of 8.5 million pounds in Massachusetts was reached in 1940.

Goucher stated that the abundance of crabs gradually increased from 1944 to 1947 until the diggers saw one or more every tide instead of one or two per year as in the period from 1933 to 1934. In the autumn of 1948, Goucher saw green crab pits over the entire flats as he had in the late 1920's, and found 350 crabs in one hole in a thatch bank. Clam production had dropped to less than a million pounds a year by this time. By 1949 lobster fishermen were again complaining that the crabs were filling their pots and eating the bait. Goucher said that 1950 and 1951 brought even more crabs and fewer clams, just like 1930 and 1931.

TEMPERATURE TRENDS

Clayton (1944, 1944a, and 1947) listed monthly mean air temperatures at New Haven, Connecticut, since 1778. Means for the coldest month of each winter smoothed by a 21-year moving average, are shown as a solid line in Figure 4. The dotted line from 1945 to 1954 indicates a moving average based on a decreasing number of years from 20 to 11. This section of the graph, therefore, is not strictly comparable with the preceding years.

The coldest period at New Haven was during the years from 1820 to 1840 when winter temperatures averaged between 23° and 24° F. In 1850 to 1860 winter temperatures averaged 24° to 25°. By 1900, temperatures for the coldest month of the winter averaged 25° to 26° F. In the 1920's, winter temperatures were averaging close to 27°, and in 1944, which is the last year in which it was possible to compute a 21-year moving average, the winter temperature averaged 27.8°. Since that time,

³ Goucher, Franklyn E. 1951. Commentary of a clam digger. Unpublished manuscript on file at U. S. Fish and Wildlife Service, Fishery Laboratory, Boothbay Harbor, Maine.

the temperature has continued to climb and the temperature average for 1954, based on 11 years' records, was 29.0° F. The highest actual temperature recorded for the coldest month of a winter was during 1953 when January averaged 34.2°. Since the 1820–1840 period, minimum winter temperatures as indicated by 21-year moving averages, have risen about 4° F.

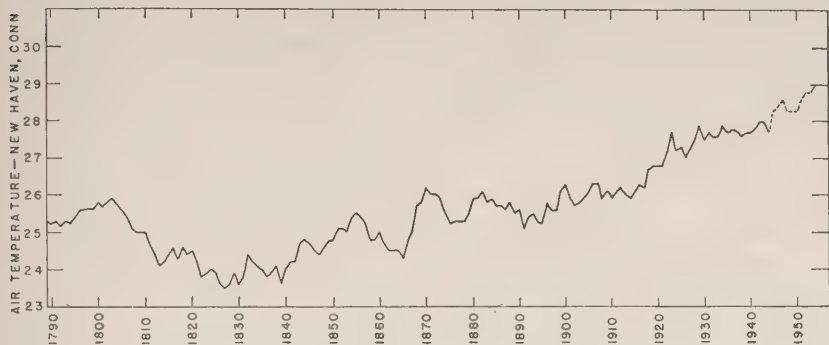


FIGURE 4.—Mean air temperatures for coldest month of the winter at New Haven, Connecticut, smoothed by a 21-year moving average from 1789 to 1944 (solid line) and by 20 to 10 year averages from 1945 to 1954 (dotted line).

Mean monthly surface water temperatures are available since: 1906 for Boothbay Harbor, Maine; 1921 for St. Andrews, New Brunswick; 1922 for Boston, Massachusetts; and 1930 for Eastport, Maine. Temperatures at these stations agree closely. Averages for the coldest month of the winter for Boothbay Harbor, Maine, are plotted in Figure 5. The coefficient of correlation for the unsmoothed air temperatures at New Haven, Connecticut, and water temperatures at Boothbay Harbor for coldest month of the winter is 0.701. This highly significant correlation permits extrapolation of water temperatures to previous years for which only air temperatures were recorded. Therefore, it is safe to conclude that water temperatures have risen along with the air temperatures indicated in Figure 4, although it is not possible to identify short-term cycles of water temperature from the air-temperature records.

TEMPERATURE TRENDS AND ABUNDANCE OF GREEN CRABS

There is good evidence that *Carcinides* is a temperate-water crab. Franklyn Goucher, the Clam Commissioner of Essex, Massachusetts, reported a mass mortality of green crabs during the cold winter of 1933–34. Broekhuysen (1937) stated that low temperatures and low salinities will kill green crabs. Another possibility is that low temperatures destroy the eggs which the females carry through the winter attached to their pleopods.

The northeastward spread of *Carcinides* may have been permitted by the warming trend which began about 1840 (Fig. 4). Smith's (1879)

observations in 1871-72 that green crabs occurred only south of Cape Cod were made at the beginning of a short-term warming cycle when winter temperatures were low. Belding (1909 and 1931) did not even list *Carcinides* as a clam predator in Massachusetts. Kingsley (1901) found no green crabs in Casco Bay, Maine. Shortly thereafter Rathbun (1905) and Morse (1909) observed green crabs in the same general area. During the late 1930's when green crabs first appeared East of Penobscot Bay, the minimum monthly water temperature at Boothbay Harbor was 32.5° F. In the late 1940's and early 1950's when the crabs spread to eastern Maine, New Brunswick and Nova Scotia, the average minimum temperature was the highest on record, 36° to 38°.

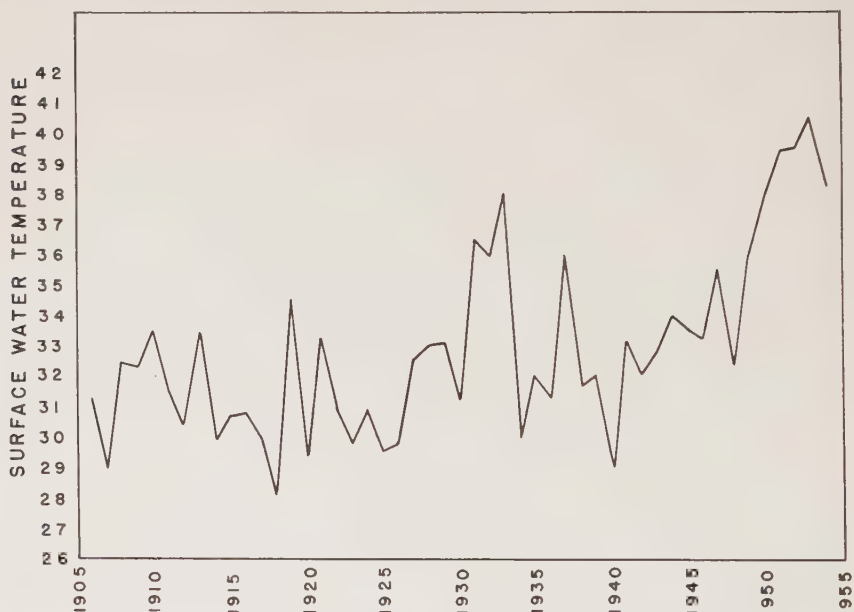


FIGURE 5.—Mean surface water temperature (°F.) for coldest month of the winter at Boothbay Harbor, Maine.

Fluctuations in the abundance of green crabs may have been caused by short-term temperature cycles (Fig. 5). The 1923-1933 warming trend coincides with the increase in green crabs in Essex, Massachusetts, as reported by Goucher. Likewise the cold winter of 1933-34 was accompanied by a great decrease in crabs.

There are some indications of a similar trend in the abundance of green crabs in southern Maine during the 1923-1934 cycle but not in northeast Maine. Four fishermen reported green crabs to be scarce in Casco Bay after the cold winter of 1933-34. They did not, however, consider the crabs "abundant" before 1934. Possibly temperatures in southern Maine

were too low to permit a great increase in crabs during this cycle, and the partial destruction of the small population went unnoticed by most of the fishermen. Apparently green crabs had not become established east of Penobscot Bay at this time.

The present warm-water cycle has been accompanied by an increase in green crabs in Massachusetts, New Hampshire, Maine, New Brunswick and Nova Scotia. This warming trend following a low of 29.1° F. in February 1940 at Boothbay Harbor has established a record high of 40.6° F. in January 1953. All of the winters from 1950 through 1954 exceeded the previous record for the mildest winter established in 1932-33. The last five mild winters doubtless permitted the spread of green crabs to eastern Maine, New Brunswick and Nova Scotia.

OUTLOOK FOR THE CLAM INDUSTRY

The discussion of the decrease in clam production, the coincident increase in green crab abundance, and increase in temperature is undoubtedly an oversimplification of the problem. The actual relationships among these factors are far more complex, and it will require much more information to clarify them. Nevertheless, the correlation between green crab abundance and clam scarcity is good enough to justify acceptance of predation as the principal reason for the decrease of soft clams in Massachusetts and Maine.

We are asked repeatedly about the future of Maine's clam industry. At the present time the outlook is very dark. Production may continue to drop, as it did in Massachusetts, if the weather remains mild. On the other hand, one or two cold winters might reduce the green crab population and allow the stocks of clams to recover.

We are continuing research on methods of controlling crabs including fencing, electrical barriers, poisons, and biological control. Further research is necessary on the severity of winter needed to kill the crabs.

We also want to know what factors control the green crab population south of Cape Cod. Fishermen say that green crabs have not increased in Rhode Island during the past 10 years. In fact, some state that the crabs have become scarce. Possibly the enemies of green crabs in those areas also may extend their range and stabilize the crab population north of Cape Cod at a level which will permit a clam fishery of moderate intensity.

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Hachey provided information on distribution of green crabs in Canada and on water temperatures at St. Andrews, New Brunswick.

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LIFE HISTORY OF THE STEELHEAD TROUT OF THE CHILLIWACK RIVER, BRITISH COLUMBIA

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ABSTRACT

Nearly 800 scale samples submitted by anglers were used to investigate features of the life history of steelhead trout (*Salmo gairdneri gairdneri*) from the Chilliwack River, a tributary of the Fraser River near Vancouver, British Columbia. After criteria for scale reading were established, data on age, fork length, sex, month and year of capture, previous spawning history and lengths at previous ages were treated statistically. Age groups are so designated as to indicate the amount of time spent in the river and in the ocean; thus 2/3 refers to fish that were 2 years in the stream and 3 in the ocean. Age composition of adult runs of steelhead trout tended to be uniform from year to year. The four major types of life history were: fish spending 2 or 3 years in fresh water and 2 or 3 years in salt water. No correlation existed between the numbers of years spent in fresh water and in salt water. Length at maturity was determined by the number of years in salt water. There was no tendency for fish of any particular age, length, or sex to return to fresh water at any particular time of year. Sixty percent of young steelhead trout migrate to salt water in the spring months as age 2 at an average length of 16.49 centimeters. Thirty-five percent go seaward as age 3 at an average length of 19.95 centimeters. A few smolts remain in fresh water until late summer. These and other findings are related to management of steelhead trout for sport fishing.

INTRODUCTION

Variability in the life history of the steelhead trout poses difficulty in the study of its populations. Adults commonly spawn in streams in the late winter or early spring but may be found in some streams in most months of the year. Young steelhead may spend from 1 to 4 years in fresh water and from a few months to 4 years in salt water before attaining maturity. Unlike Pacific salmon (*Oncorhynchus* spp.) steelhead trout may survive to spawn more than once. To sample fish of a year class at various ages would thus involve stream sampling at age I, stream and ocean sampling at older ages. Even relating numbers of downstream migrants to numbers of returning adults may require 7 years of sampling to obtain the statistics for one year class. Further complications from straying of adults (Pautzke and Meigs, 1940), the incidental commercial fishery, and the effect of weather conditions on the sport fishery (Larkin 1950), all contribute to make population studies more difficult. In conse-

quence, many features of the life history can be studied conveniently only by inference from scale readings, despite the shortcomings of this technique. The present paper is based on scale readings from 784 scale samples from anglers' catches in the years 1948 to 1953 from the Chilliwack River. These collections were supplemented by samples of young fish taken from the river in 1951-52.

The Chilliwack River is a tributary of the Fraser River. It joins the Fraser near Chilliwack, British Columbia, approximately 50 miles from New Westminster where the Fraser enters the Georgia Straits. The sport fishery is concentrated on the lower 10 miles of the river because the headwaters are closed to angling.

METHODS OF COLLECTION, PREPARATION, AND INTERPRETATION OF SCALES

The 784 scale samples of adult steelhead trout used in this study were mostly obtained by anglers who submitted them in envelopes provided for the purpose by the British Columbia Game Commission. Information on sex, length, weight, and date of capture of the fish was requested. Except for data on weight, the information supplied was found to be reliable. Only 14 samples were discarded as entirely unsuitable. Scales of adult fish were impressed on celluloid strips with a jeweller's press. Scale impressions were read at a magnification of 18 diameters by means of a Bausch and Lomb microprojector. Central portions of scales were read at a magnification of 37.4 diameters.

Anglers were requested to take scales "from high up on the side of the fish behind the dorsal fin". Carlander (1950) has pointed out the need for taking scales from the same place on each fish if the results of back calculations are to be comparable. Series of 23 scale samples taken from various parts of three steelhead trout, indicated that there is a large elliptical area on the side of the fish (Fig. 1) in which deviation in dorsoventral scale diameter from a "type station" below and behind the dorsal fin is less than 10 percent and usually less than 5 percent. Scales from this area of small deviation tend to be oval-shaped and symmetrical, whereas scales from other parts of the body, especially those showing greatest deviation in size from the type station behind the dorsal fin, tend to be asymmetrical and readily recognizable. Asymmetrical scales and scales with regenerated central portions were not used.

Small steelhead trout were collected by seining and by angling in the Chilliwack River. Scales of these fish were mounted in a Canada balsam-dioxane medium and examined under a microscope at a magnification of 40 diameters.

Interpretation of steelhead trout scales requires establishing of criteria for fresh-water annuli, change from fresh-water growth to salt-water growth, salt-water annuli, and spawning checks. A fresh-water annulus is detectable on a steelhead scale as a distinct cutting off of incomplete circuli by a complete circulus which marks the commencement of rapid growth in the spring (*cf.* Creaser, 1926). Samples of young trout taken in

all months of the year suggest a period of rapid growth extending from April to October, little growth from October to March and formation of the annual check in March. Sea growth is distinguished from fresh-water growth by its widely spaced circuli (Menzies, 1931). Steelhead scales show a pronounced difference between fresh-water and sea growth that can usually be delimited to two circuli—the last circulus of fresh-water and the first of sea growth. Sea growth generally commences immediately after formation of a fresh-water annulus or after a little additional fresh-water growth. Smolts generally migrate seaward in March, April, and May. A

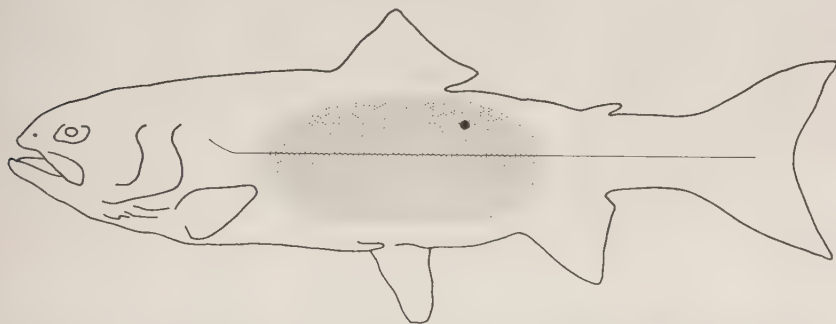


FIGURE 1.—Adult steelhead showing area on side of fish in which deviation in dorsoventral scale diameter is small by comparison with the type station below and behind the dorsal fin.

few smolts can be taken in the river in July and August. In consequence, the sea growth does not always immediately follow a fresh-water annulus. Annuli formed in salt water do not show cutting off of circuli, nor is there a sharply defined commencement of spring growth. A typical ocean annulus consists of a crowding together of circuli in a noticeable dark band (Fraser, 1917; Rich and Holmes, 1928). The central point of the crowded circuli is taken as the annulus.

When adult fish enter fresh water they rarely take food, and length increases little, if at all. As the fish approach maturity, unevenness of the scale margin caused by resorption becomes progressively more pronounced. On most scales resorption does not proceed past the last-formed ocean annulus but some scales may be rendered useless for age determination. Circuli added after spawning enclose the uneven edge of the scale, leaving a distinctive spawning scar which can be recognized on subsequent return of a fish to fresh water (Blair, 1937).

The terminology denoting events in the life history of steelhead trout can be confusing. In this study the number of complete years in fresh water is indicated on the left-hand side of a diagonal stroke. On the right side of the stroke is indicated the number of years between smolt migration and the time spawning would have occurred if the fish had not been captured. Thus a $2\frac{1}{2}$ fish is one which spent 2 years in fresh water,

but which shows on its scales only one ocean annulus together with a second period of ocean summer growth. Such a fish would be 4 years old at spawning in March. At capture, probably in the period from November to February, it would be not yet 4 years old. Spawning checks are denoted thus 2/2s 3; the 3 again denoting a year of life which would have been completed if the fish had not been caught. Table 1, which lists events in the life history of four major age groups of the 1949 collection of steelhead trout from the Chilliwack River, shows the different categories of fish in a single year's collection and the time relationships that exist among them.

Estimation of lengths at previous ages from scales of adult steelhead trout is handicapped by resorption of the scale margins at maturity. Mottley (1942) has demonstrated that logarithms of scale measurements of *Salmo gairdneri kamloops* provided an unbiased estimate of logarithms of fish lengths. In this study estimations of lengths, made only for pre-smolt ages, were obtained by direct conversion of dorsoventral scale diameters to average fork lengths. No proportionate calculations were made; rather, a particular scale diameter corresponding to an average fork length was determined from a log-log regression of fork length on scale diameter, based on observations of 132 pre-smolt steelhead.

TABLE 1.—Events in the life history of four age groups of a single year's (1949) collection of adult steelhead trout from the Chilliwack River

[All events assumed to occur in March, asterisks indicate migration as smolts]

Life history event	Age groups			
	2/2	3/2	2/3	3/3
Deposited as eggs by spawning run of.....	1945	1944	1944	1943
River life, completion of				
First year.....	1946	1945	1945	1944
Second year.....	1947*	1946	1946*	1945
Third year.....	....	1947*	....	1946*
Ocean life, completion of				
First year.....	1948	1948	1947	1947
Second year.....	1949	1949	1948	1948
Third year.....	....	....	1949	1949

AGE COMPOSITION OF RUNS OF ADULT STEELHEAD TROUT

Table 2 summarizes the age composition of runs of adult steelhead trout in the Chilliwack River from December to March of the years 1948–49 to 1952–53.

In each winter, the run of adults is made up of a mixture of year classes, ranging in age from 2 to 7 years. The predominant age groups in each year are 2/2, 2/3, 3/2, 3/3. Together, these four groups made up 96.8 percent of the catch for the 5-year period. No significant correlation exists between the numbers of years spent in fresh and in salt water. Despite the apparent uniformity of age composition in the 5 years, chi-

TABLE 2.—*Age composition of anglers' catch of adult steelhead trout from the Chilliwack River from December to March of the seasons 1948-49 to 1952-53*

Season of adult run	Age: fresh water/salt water											
	1/1	1/2	1/3	2/1	2/2	2/3	2/4	3/1	3/2	3/3	3/4	4/3
1948-49.....												
Number of fish....	...	2	1	1	38	38	...	...	19	24	...	1
Percentage.....	...	1.6	0.8	0.8	30.7	30.7	...	...	15.3	19.4	...	0.8
1949-50.....												
Number of fish....	...	2	2	...	27	19	...	...	13	8	1	...
Percentage.....	...	2.7	2.7	...	37.0	26.0	...	...	17.8	11.0	1.4	...
1950-51.....												
Number of fish....	...	4	2	...	39	29	...	...	12	18	1	...
Percentage.....	...	3.8	1.9	...	36.8	27.4	...	...	11.3	17.0	0.9	...
1951-52.....												
Number of fish....	...	...	...	...	58	55	...	1	58	28	1	...
Percentage.....	...	...	...	...	28.9	27.4	...	0.5	28.9	13.9	0.5	...
1952-53.....												
Number of fish....	1	...	1	1	77	95	1	...	34	55	...	1
Percentage.....	0.4	...	0.4	0.4	28.9	35.7	0.4	...	12.8	20.7	...	0.4
Total.....	1	8	6	2	239	236	1	1	136	133	3	3
Percentage.....	0.1	1.0	0.8	0.3	31.1	30.7	0.1	0.1	17.7	17.3	0.4	0.4

square tests indicated statistically significant departures from uniformity between years, either when all age groups, or only the four major age groups are considered. This heterogeneity may be caused by slight differences in the relative size of year classes. The record of the percentages contributed by the year classes 1942 to 1949 to the catches in the years 1948-52 (Table 3) demonstrates that the 1947 year class contributed: as 4-year-old fish, 38.7 percent of the 1950-51 catch; as 5-year-old fish, 56.3 percent of the 1951-52 catch; and as 6-year-old fish, 21.1 percent of the 1952-53 catch. Each of these contributions was large in comparison with the return of other year classes. To provide a rough measure of differences among the sizes of the year classes, their percentage contributions to the catch of various years are summed in the bottom row of Table 3. Although these sums could probably be influenced, by varying mortality

TABLE 3.—*Year-class composition of the total anglers' catch of steelhead trout from the Chilliwack River in the winters 1948-49 to 1952-53*

[See text for explanation]

Season of capture	Percentage contributed by year class							
	1942	1943	1944	1945	1946	1947	1948	1949
1948-49.....	0.8	19.4	46.0	31.5	2.4	...	...	...
1949-50.....	...	1.4	12.4	43.8	39.7	2.7	...	...
1950-51.....	...	...	1.8	17.0	38.7	38.7	3.8	...
1951-52.....	...	...	...	0.5	13.9	56.3	29.4	...
1952-53.....	...	...	...	...	0.4	21.1	48.5	29.3
Total ¹	...	...	...	92.8	95.1	118.8	...	...

¹ Sum of percentage contributions; given only for year classes represented by all major age groups i.e. 4-, 5-, and 6-year-old fish.

rates, by variation in age composition, and possibly by other unsuspected factors, they suggest that an explanation for the significant variation in age composition could lie in the difference in the strength of year classes.

LENGTHS OF THE AGE GROUPS

The fork length attained by steelhead trout at maturity ranged from approximately 25 centimeters to more than 100 centimeters (Table 4). The number of years spent in fresh water is not significant as a factor determining size at maturity. Moreover, since the number of years in fresh water is not correlated to the number of years in salt water (Table 2), fork length is a function of the period of ocean life rather than of total age. The annual increments of fork length diminish with each year of ocean life; fish which spent 1 year in the ocean averaged roughly 23

TABLE 4.—Mean length (centimeters) of steelhead trout of various ages from the Chilliwack River, 1948 to 1953

Age group	Number of fish	Mean fork length	Age group	Number of fish	Mean fork length
1/1.....	1	48.3 }	1/3.....	6	81.0 }
2/1.....	2	47.5 } 47.2	2/3.....	235	81.0 }
3/1.....	1	45.7 }	3/3.....	126	81.8 }
			4/3.....	3	83.0 }
1/2.....	8	70.9 }			
2/2.....	234	69.8 } 70.1	2/4.....	1	96.5 }
3/2.....	134	70.1 }	3/4.....	3	85.1 }
					87.9 }

centimeters shorter than those with two years of ocean life, whereas those with 3 years at sea were only about 11 centimeters longer. However, since weight varies approximately as the cube of the length, increments in lengths in longer fish are associated with bigger gains of weight. Thus the decline in growth from the viewpoint of weight is not so marked as the length differences suggest. The group that spent 4 years in salt water was made up entirely of second spawners which might also account for their lesser gain.

SEX AND AGE OF STEELHEAD CAPTURED ON DIFFERENT DATES

The summary of data pertaining to sex and age of steelhead taken in December, January, February, and March of the years 1948-49 to 1951-52 (Table 5) offers no suggestion that fish of any particular fresh-water age or salt-water age tend to return in any particular month. Larkin (1950) reported that for the 1948-49 catch in the Chilliwack River the older and longer fish tended to be caught early in the season. This trend was not evident in following years. The mean number of years spent in fresh water is not significantly different in males and females. Females remain significantly longer in salt water than males but this difference is caused at least partly by the greater return of females as second spawners.

TABLE 5.—*Mean age (fresh/salt) of adult steelhead trout caught in the Chilliwack River in December to March, 1948-49 to 1951-52*
 [Number of fish in parentheses]

Season of capture	December		January		February		March		December-March	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1948-49.....	2.3/2.5 (6)	2.7/2.8 (14)	2.3/2.5 (11)	2.3/2.7 (22)	2.3/2.2 (27)	2.3/2.5 (38)	2.0/3.0 (2)	1.6/2.3 (3)	2.3/2.3 (46)	2.3/2.6 (71)
1949-50.....	2.0/2.2 (20)	2.2/2.4 (17)	2.3/2.3 (3)	2.4/2.8 (5)	2.5/2.0 (2)	2.2/2.5 (4)	2.3/2.3 (3)	1.7/2.4 (8)	2.1/2.2 (28)	2.1/2.5 (34)
1950-51.....	3.0/3.0 (1)	2.0/2.5 (2)	2.1/2.4 (37)	2.3/2.6 (37)	2.0/2.2 (4)	2.5/2.5 (2)	2.3/2.2 (6)	2.4/2.4 (5)	2.1/2.4 (48)	2.3/2.6 (46)
1951-52.....	2.3/2.4 (14)	2.5/2.6 (29)	2.5/2.3 (44)	2.3/2.6 (53)	2.8/2.0 (8)	2.4/2.3 (17)	2.3/2.4 (8)	2.7/2.4 (16)	2.5/2.3 (74)	2.4/2.5 (115)
Average.....	2.2/2.3 (41)	2.5/2.6 (62)	2.3/2.4 (95)	2.3/2.6 (117)	2.4/2.2 (41)	2.3/2.4 (61)	2.3/2.4 (23)	2.3/2.4 (32)	2.3/2.3 (196)	2.3/2.5 (272)

The sex ratio in the 4-year period was 196 males to 272 females. Despite a lack of significant differences among values of the sex ratio by month and year, the ratio did vary significantly according to age group (Table 6). The males make up half the total of the 2/2 and 3/2 fish but only slightly more than a third of the 2/3 and 3/3 groups. The difference is only partly due to the greater incidence of second spawning in females; females are generally older than males at first spawning also.

TABLE 6.—Numbers of male and female steelhead trout of various ages and differing spawning history from the Chilliwack River from 1948-49 to 1951-52

Age group	Males		Females		Total	
	First spawners	Previous spawners	First spawners	Previous spawners	Males	Females
2/2.....	78	..	77	1	78	78
3/2.....	41	..	56	..	41	56
2/3.....	43	2	73	15	45	88
3/3.....	18	..	42	6	18	48
Total.....	180	2	248	22	182	270

LENGTHS OF STEELHEAD TROUT CAPTURED ON DIFFERENT DATES

The mean fork lengths of male and female steelhead trout taken in the Chilliwack River from December to March (Table 7) exhibited no significant month to month trends. The samples throughout the winter can be considered relatively homogeneous with respect to length. Seemingly, the additional few months spent in salt water by fish which return to fresh water late in the winter, are not a period of appreciable growth.

TABLE 7.—Mean fork length (centimeters) of male and female steelhead trout caught from the Chilliwack River, December to March, 1948-49 to 1951-52

[Number of fish in parentheses]

Season of capture	December		January		February		March	
	Males	Females	Males	Females	Males	Females	Males	Females
1948-49....	80.8 (6)	79.0 (14)	80.0 (11)	75.9 (22)	74.2 (27)	73.1 (38)	68.6 (2)	71.9 (3)
1949-50....	73.4 (20)	72.9 (17)	81.3 (3)	76.7 (5)	64.8 (2)	87.6 (4)	81.5 (3)	73.4 (8)
1950-51....	84.6 (1)	72.4 (2)	77.7 (37)	74.9 (37)	76.2 (4)	71.1 (2)	76.7 (6)	77.0 (5)
1951-52....	75.9 (14)	74.2 (29)	75.9 (44)	73.9 (53)	68.3 (8)	70.9 (17)	74.7 (8)	72.4 (16)
Mean.....	75.7 (41)	74.9 (62)	77.2 (95)	74.7 (117)	72.6 (41)	73.4 (61)	75.7 (19)	73.1 (32)

NUMBERS AND LENGTHS OF AGE GROUPS OF SMOLTS

Most of the steelhead trout migrated to the ocean after 2 or 3 years in the Chilliwack River (Table 8). Over 60 percent went to sea after 2 years in fresh water, and 35 percent after 3 years in fresh water. The proportion of 2- and 3-year-old migrants did not vary significantly from year to year, neither in comparisons based on the year of capture as adults or rearranged for year of seaward migration. The percentages of yearling

TABLE 8.—*Age and fork length (centimeters) at migration of steelhead smolts which returned to the Chilliwack River as adults in the years 1948-1953.*

Year of capture as adult	Age at smolt migration				Total or average
	1	2	3	4	
1948-49					
Average fork length.....	11.1	16.0	19.3	21.1	17.0
Number of fish.....	3	77	43	1	124
Percentage of yearly total.....	2.4	62.1	34.7	0.8	....
1949-50					
Average fork length.....	10.0	15.7	20.8	24.8	17.1
Number of fish.....	4	46	22	1	73
Percentage of yearly total.....	5.5	63.0	30.1	1.4	....
1950-51					
Average fork length.....	12.3	16.3	19.3	22.4	17.0
Number of fish.....	6	68	31	1	106
Percentage of yearly total.....	5.7	64.2	29.2	0.9	....
1951-52					
Average fork length.....	....	17.0	19.8	....	18.3
Number of fish.....	....	113	88	....	201
Percentage of yearly total.....	....	56.2	43.8	....	....
1952-53					
Average fork length.....	9.9	16.6	20.4	23.2	18.0
Number of fish.....	2	174	89	1	266
Percentage of yearly total.....	0.8	65.4	33.5	0.3	....
Years lumped					
Average fork length.....	11.1	16.5	20.0	22.9	17.6
Number of fish.....	15	478	273	4	770
Percentage of yearly total.....	2.0	62.1	35.4	0.5	....

migrants, though consistently small, showed significant variation from year to year. The average length of the migrants increased significantly with each added year of residence in fresh water. The variations from year to year in the fork length of 2- and 3-year-old migrants are of doubtful statistical significance; they are not related to the fluctuations in the strength of year classes.

AUTUMN MIGRATION OF SMOLTS

The usual start of rapid sea growth on steelhead scales immediately after a fresh-water annulus, suggests migration to the sea in March and April. On 44 of 754 scale samples, additional fresh-water growth between

a fresh-water annulus and salt-water growth circuli indicated that some young steelhead trout may spend a few months more in fresh water before migrating seaward than do the majority of their age group. Samples taken on the Chilliwack River in August confirmed that some smolts were present in the river at that time. Of the 44 autumn migrants, 21 were males; 26 were from the 2/2 age group, 14 from the 2/3 age group, 2 from the 3/2 age group, 1 from the 3/3 group, 1 from the 1/2 group. On the average, the autumn migrants were smaller in the spring prior to migration than smolts which went to sea in the spring. In the additional months in fresh water they added an average of 4 centimeters, sufficient to bring them to a size roughly equal to spring migrants of the same age group.

SMOLT LENGTH AND LENGTH AND AGE AT CAPTURE

For fish which had not spawned previously a study was made of the correlation between the estimated fork length at smolt migration and: fork length at capture as adults for each of the four major age groups for each year; the increment in fork length from smolt migration to the first salt-water annulus. For the 1949-50 sample, the first of these correlations

TABLE 9.—*Adult fork length (centimeters) at capture and estimated mean fork length at smolt migration for four age groups of Chilliwack River steelhead trout, 1948 to 1953*

Season of capture	Age group							
	2/2		2/3		3/2		3/3	
	Smolt	Adult	Smolt	Adult	Smolt	Adult	Smolt	Adult
1948-49. . . .	16.5	70.9	15.3	78.7	19.0	71.6	19.5	80.5
1949-50. . . .	16.2	67.3	15.2	81.0	21.5	70.6	19.6	82.0
1950-51. . . .	17.6	70.6	15.3	82.0	18.9	69.6	19.8	82.8
1951-52. . . .	17.9	68.6	16.1	80.5	20.2	69.1	18.9	80.0
1952-53. . . .	16.9	70.6	16.4	82.0	20.1	71.1	20.6	82.8

was repeated for the logarithms of the lengths. None of these correlations was significant. However, smolt fork length for the 2/2 group was greater than that in the 2/3 group for all 5 years of samples *i.e.*, the smaller 2-year-old smolts on the average spent the greater number of years in the ocean. Table 9 shows the estimated mean fork lengths of smolts and the mean fork lengths of adults at capture for the four major age groups for each year of the adult fishery. For the 5-year period, analysis of variance shows that at smolt migration the 2/2 fish were significantly larger than the 2/3 fish. However, the 3/2 and 3/3 age groups did not exhibit a similar difference.

MANAGEMENT OF STEELHEAD

Variability is a major feature of the life history of steelhead trout of the Chilliwack River. Most trout return as mature adults at an age of 4, 5, or

6 years. In the 5-year period under study, roughly half of the steelhead returned as 5-year-old fish, one third as 4-year-olds, one fifth as 6-year-olds, and a few as 2- or 7-year-olds. Such variability should ensure a sufficient overlapping of year classes to dampen any great fluctuation of year-class strength. Although the analysis of age composition for the Chilliwack River suggests that the 1947 year class was slightly larger than other year classes, the difference was barely large enough to be detectable. It would be justifiable then to assume that the strength of the year classes varied only moderately. The nearly constant composition of the adult population with respect to age at seaward migration would suggest uniformity in the numbers of smolts produced in the river each year. This steady rate of reproduction could be explained by a limited productive capacity of the river or by density-dependent limitations in either the fresh- or salt-water environment. The influence of smolt size on age at maturity evident in some age groups would exert a further dampening agent if smolt size is in turn related to the size of the population of smolts. The sport and commercial fisheries may contribute to the smoothing out of fluctuations in the size of populations of adults. Regardless of what factors are involved, however, the fishery evidently exerts little influence on the population of steelhead trout in the Chilliwack River, except, perhaps to crop off an unneeded surplus. Conditions for sport fishing fluctuate widely from year to year. The catch, as indicated by the number of samples obtained for study, may be 5 times as big in some years as in others. Such variations do not appear to be reflected in any major dissimilarity of year-class size in the past 5 years.

The relationship of low flows in summer months to production of coho salmon (*Oncorhynchus kisutch*) has been demonstrated by Neave (1949) and it seems probable that a similar relationship may be important for steelhead trout, particularly since they usually spend 2 years or more in fresh water before migration, whereas the coho salmon spend but 1 year in fresh water. Although low flows in any one year would affect more than one year class of steelhead, this effect would be offset by the variation in the period in salt water; that is the effects would be distributed over more than 2 future year classes. It might be surmised then, that declines in populations of steelhead from periods of low flows would be gradual. Similarly, improvement in runs of steelhead trout would be spread out over several year classes, and the benefits measurable in the fishery over several years.

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PROBLEMS OF RESERVOIR MANAGEMENT

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ABSTRACT

The reservoir construction program during the last few years in Oklahoma has effected a tremendous increase in fishing opportunities. The answers to many fishery management problems arising out of the reservoir construction have been answered through cooperative endeavor of Federal agencies, state agencies, and schools of higher learning. Artificial reservoirs are so prolific in fish production that overpopulation is the main problem. Much more efficient commercial fish and sport fish harvest programs are needed, however, public resistance is at present the principal impediment to better management.

INTRODUCTION

The states of the Southwest have few natural lakes. Oklahoma is one of those states where, originally, angling opportunities were restricted to a very few oxbows and not too many suitable streams. Today, it has over 235,000 acres of artificial impoundments constructed by Federal, state, or municipal funds plus numerous other smaller lakes which have been constructed by private, industrial, and conservation interests. Nine of the larger reservoirs constructed by the Corps of Engineers contributed approximately 150,000 acres of water or more than 60 percent of the total reservoir area for the state. The largest of these impoundments is Denison Reservoir (located in Oklahoma and Texas) with 93,080 acres and the smallest is Heyburn Reservoir with 1,070 acres.

Most of these dams have been constructed across streams which heretofore provided little suitable habitat for fish because of the extreme fluctuation of flow. The dams have transformed unstable streams to more stable lake-type habitats (Aldrich, 1945). Additional water areas have been created which are more productive, acre for acre, than the original streams. The tremendous number of fishermen using these reservoirs indicates the importance of this resource to the anglers.

During fiscal Year 1940-41, approximately 4 percent of the residents of Oklahoma purchased fishing licenses. By 1951-52, licensed fishermen had increased to about 17 percent of the total population; still later, in 1954, it is estimated that the figure has risen to almost 20 percent. During the 10-year period ending in 1952, the sale of non-resident fishing licenses increased from 8,256 to 53,099. Unquestionably, the completion of flood-control reservoirs which began around 1942 was the most important single factor in this increase of license sales.

The number of people visiting the 10 reservoirs of the Tulsa District, Corps of Engineers, during 1953, as estimated from traffic counters, was approximately 8,900,000. The two reservoirs with the highest counts were Denison Reservoir, on the Red River, with approximately 3,900,000 visitors, and recently impounded Fort Gibson Reservoir, on the Grand River, with approximately 1,200,000 visitors. Thus, the construction of reservoirs in Oklahoma has given the state a very high position in angling opportunities.

COOPERATIVE RESEARCH AND MANAGEMENT

The important contribution of the large reservoirs to Oklahoma's fish and wildlife future carried with it a management responsibility that could not be long ignored. The early development of superb angling on the new reservoirs resulted in the tendency to ignore the fish-management problems for several years, but eventually the demand for a long-range program prevailed.

The Biennial Report of the Oklahoma Game and Fish Commission (1944-1945), recognized the need for research in the fishery field and suggested the major institutions of higher learning as possible cooperators. The two objectives outlined for the proposed program were (1) to provide sufficient scientific basis for the administration of the fish and wildlife resources, and (2) to serve as a means for training technical personnel. From the beginning, everyone was aware of the State's responsibility for the management of the fish and wildlife resources of Federally sponsored impoundments. However, it was also soon recognized that the objectives of the fish and wildlife program should be related to the agriculture, other land and water use, and to general resource-development programs of each reservoir project. This called for coordination.

In 1945, the Oklahoma Game and Fish Department and District Engineer, Tulsa District, Corps of Engineers, agreed that the existing arrangements for coordination between the two agencies were not producing adequate results. It was decided, therefore, that the Director of the Game Division of the Oklahoma Game and Fish Department should be made available to work on the District Engineer's staff for a period of not less than 6 months. It was agreed also that the Director of the Fisheries Division should later be made available on the same basis. The purpose was to educate personnel in the administration and engineering aspects of project planning and operation in the Corps of Engineers. On the basis of this experiment, it was decided later that one of the Game and Fish Department technicians should remain with the Corps of Engineers as an employee responsible for the proper integration of the biological phase of the program. Since that time, it has been common for the two agencies to exchange key personnel from time to time.

In 1947, the Cooperative Fisheries Research Laboratory was established on the campus of the University of Oklahoma. A similar research agreement was made about the same time between the Oklahoma Game and Fish Department and Oklahoma A. and M. College. From this point,

cooperation among interested state and Federal agencies was accomplished with a minimum of effort. Boats, motors, nets, various types of scientific equipment, and even personnel were pooled by the agencies interested in completing certain research and management projects. In the beginning, the work consisted primarily of pre-impoundment surveys of some of the major streams. Among these studies was that sponsored jointly by the Oklahoma Game and Fish Commission, Oklahoma A. and M. College, and the Corps of Engineers, which dealt with a pre-impoundment study of the Illinois River (Moore and Paden, 1950).

An important development in this cooperation came in 1948 when the Director of the Oklahoma Game and Fish Department called a meeting, which led to the organization of the Oklahoma Fish and Game Council. The council provided for official cooperation among the Oklahoma Game and Fish Department, the U. S. Fish and Wildlife Service, the University of Oklahoma, Oklahoma A. and M. College, and the Tulsa District, Corps of Engineers, in fish and wildlife research and management of Corps of Engineer's reservoirs in Oklahoma. This council is still in existence and is efficiently functioning in an investigative and coordinating capacity. A total of nine research projects have been completed since 1948 under the program.

Four of the students assigned projects have been candidates for Ph. D. degrees, while the other five worked toward Master's degrees. Each student has been required to spend from one summer period of 3 months to intermittent periods over longer intervals on a corps of Engineers' reservoir. After completion of the field phase of the project, the student returns to his graduate school where he completes the laboratory work and prepares a report for the council.

The council itself selects research projects and provides general supervision. Immediate direction of the project remains with the student's major professor. Although most of the details of the research are handled by the major professor, the close coordination allows the fish and wildlife administrators a voice in the projects. One of the important elements of the program has always been the effort of college professors to pattern the investigative phase of their program along the lines that would be most applicable to management.

The major research projects have been analyses of the fish populations in relation to reservoir management. A pre-impoundment biological survey was made at Wister Reservoir in southeastern Oklahoma at the time the reservoir was being impounded (Hall, 1951). Two years later another student made a post-impoundment study on the same project (Latta)¹. This type of study has provided invaluable comparisons between reservoir fish and fishing and the original stream condition. One of the latest studies dealt with the commercial fishing activities on Lake Texoma (Houser)². Another student studied a natural, but unusual concentration and harvest

¹ Latta, William Carl. 1952. A post-impoundment biological fishery survey of Wister Reservoir, Poteau River, Oklahoma. Rep. to Okla. Fish and Game Council.

² Houser, Alfred. Commercial fishing census on Lake Texoma. (Final Rep. to Okla. Fish and Game Council expected in 1955).

of crappie as well as an artificial reproduction of the same phenomenon at the Canton Reservoir in northwestern Oklahoma (Hancock³. The work of the other five students has been equally as important in providing information vital to the management program (Jenkins,⁴ Sublette,⁵ Orr,⁶ Buck and Cross⁷).

The present occupations of the nine students who completed projects are also of interest. Four now occupy important research and administrative positions in the Oklahoma Game and Fish Department, including those of Director of the Fisheries Division, and the Director of the Oklahoma Fisheries Research Laboratory; two are college professors; one is the manager of a large minnow and goldfish hatchery; and the other two are employed by other states. As can be seen, one of the important functions of providing much needed personnel to the State's program has been realized. This alone has been worth more than the cost of the program.

Actually, the Oklahoma Fish and Game Council cannot be termed spectacular. Its creation was a logical development. Such an organization could have been valuable even though it accomplished nothing other than the establishment of understanding and good will among the working agencies. Each member has, by keeping himself informed as to the activities of other agencies, come to recognize the objectives and problems of those agencies. The honest, uninhibited discussions at the conference table have dispelled suspicion and made for harmonious development of the fish and wildlife resources of the reservoirs of Oklahoma.

ECOLOGICAL REVIEW OF RESERVOIRS

Productivity of reservoirs.—Much information has been accumulated over the country during the past 10 years relative to the ecological aspects of artificial reservoirs and much more will be learned during the next 10 years. One thing is certain—reservoirs in the Southwest are not biological deserts, as has sometimes been suggested. The reproductive potential of the fish of these stable bodies of water is great—so great that it becomes the most serious management problem. The waters become so crowded with fish that problems of overpopulation and the associated retardation of growth rate are sooner or later felt. Grand Lake, a 45,000-acre lake in northeastern Oklahoma, after approximately 10 years of impoundment supports a superabundance of sport, commercial, and rough fish. Eight widely separated and diversified areas totaling 15.75 acres, which were

³ Hancock, Hunter M. 1954. Investigations and experimentation relative to winter aggregations of fishes in Canton Reservoir, Oklahoma, Part I. Rep. to Okla. Fish and Game Council.

⁴ Jenkins, Robert Merle. 1949. A biological fishery survey of the Great Salt Plains Reservoir. Rep. to Okla. Fish and Game Council.

⁵ Sublette, James Edward. 1953. The ecology of the macroscopic bottom fauna in Lake Texoma. Rep. to Okla. Fish and Game Council.

⁶ Orr, Orty E. A fishery population and management study of Heyburn Reservoir. (Final Rep. to Okla. Fish and Game Council expected in 1955).

⁷ Buck, Homer and Frank Cross. 1951. Early limnological and fish population conditions of Canton Reservoir, Oklahoma, and fishery management recommendations. Rep. to Okla. Fish and Game Council.

treated with rotenone during 1949, produced an estimated 570,000 individual fish weighing 9,818 pounds. A maximum of 1,031 pounds of fish per acre were recovered at one station, and the average was 623 pounds for the whole area treated (Thompson)⁸. There is no evidence that older reservoirs are less productive than new reservoirs in pounds of fish per acre. The annual crop potential depends more upon the size of the harvest than on the age of the reservoir. The higher the rate of harvest the greater should be the rate of replenishment.

Overfishing.—The possibility of overfishing in southwestern reservoirs is so remote, that it is seldom considered by technicians. Even the removal of commercial fishes would need to be many times greater than the present maximum to approach the annual rate of replenishment. One unusual hook-and-line harvest was reported for Canton Reservoir during the winter of 1950. Between January 10 and March 19 (69 days), over 500,000 legal-sized (6 inches total length) crappie were taken from a small narrow cove of the reservoir, approximately 100 yards long. The estimated total weight of the fish was 132,336 pounds. This rate of catch was over 22 tons per acre for the 3-acre cove, or approximately 27 pounds per acre for the whole lake (Buck and Cross)⁹. A recent report to the Oklahoma Fish and Game Council explains the phenomenon in detail (Hancock)¹⁰. After this harvest, the growth rate of crappie increased as much as 1 inch during the first year of life. Unfortunately, the severe drouth that followed altered the lake level so that the effects on angling could not be ascertained.

Overpopulation.—Overpopulation is a relative term. One stream may support one-tenth of the population per unit area as another, yet the resulting growth rate may be comparable in the two. Although most reservoirs of the Southwest support more pounds of fish per acre than did the original stream, the growth rate in the reservoir is usually much greater, at least initially. The tendency toward overpopulation in reservoirs should not be surprising. Generally, the same species which now inhabit the reservoirs have, over a period of thousands of years, geared their reproductive potential to compensate for the hazards of extreme water-level changes of streams.

Information now available supports the statement that, "Angling in the Southwest is as good as the growth rate of the species sought." This statement, of course, is general and not without some exception. The basis of the statement lies in the fact that slow growth eliminates the most plentiful young fish too small to be taken (Thompson,¹¹ Jenkins¹²). It is recognized, for example, that the overwhelming majority of the white bass in southern waters are in their third year of life or younger. Should the growth rate of that species become so slow that the third-year fish is

⁸ Thompson, William H. 1950. Investigation of the fisheries resource of Grand Lake. Okla. Fish. Res. Lab. Rep. No. 18.

⁹ See footnote 7.

¹⁰ See footnote 3.

¹¹ See footnote 8.

¹² See footnote 4.

too small to be desirable, that species will almost be eliminated from the creel. Because of the high reproductive potential of channel catfish in reservoirs, it is not unusual to observe that species growing so slowly that it requires 4 to 6 years to reach Oklahoma's 10-inch (total) legal length. Thus it is not inconceivable that more than 90 percent of a catfish population may be eliminated from the creel.

The effects of overpopulation of either rough or sport species upon growth rate are thought to be approximately the same. The problem of interspecific and intraspecific competition needs further clarification. It has been observed, however, that black bass, channel catfish, and other species will "stunt" in waters teeming with gizzard shad which is readily available as an important food item. It has also been observed that a species introduced into overpopulated waters may find a favorable niche, which permits initially fast growth, but that this niche is filled rapidly as the species becomes more numerous and the growth rate drops. By now, it is generally accepted that rough fishes compete and exert a population pressure which has an important effect on species composition (Ricker and Gottschalk, 1940; Johnson, 1949). Few of us doubt that the control of rough fish increases the numbers and welfare of the sport species of the same reservoir.

In most reservoirs some of our favorite sport species are just as prolific as rough fish. Channel catfish and white crappie are generally two of the most successful in reservoirs. Bluegill and green sunfish usually become too numerous during the first 2 years and are not important in the creel thereafter. White bass eventually become very numerous, but the short life span and resulting rapid turnover of this species may favor the maintenance of optimum numbers. The die-off may not be rapid enough, however, to stave off the seemingly inevitable eventual retardation in rate of growth. An extremely high rate of harvest for white bass has developed in some areas but the effects upon the population are yet to be determined.

Overpopulation of rough and commercial species now seems to be generally recognized by sportsmen. The talk that "rough fish are taking over", is prevalent. Admittedly this much quoted expression has been conveniently used to summarize the situation to a public which is often reluctant to accept overpopulation and the need for a program of extensive commercial fishing. We must remember, nevertheless, that in many waters sport species are equally bad offenders. If we are to continue to receive the best fishing from our reservoirs, we must eventually devise more effective means for controlling sport fishes as well as rough fishes.

Status of black bass.—In some of the most turbid reservoirs, black basses do not reproduce efficiently. Some older reservoirs that produce fingerlings in large numbers, often produce poor black bass fishing. In many other lakes, good to excellent black bass fishing persists for years. Despite certain exceptions, it can be stated that the black bass has not been a good "big lake" species, particularly in impoundments that are 5 years old or older. In view of the change of habitat created in a reservoir, it is not surprising that large populations of black bass do not always persist in

some older reservoirs or that previously unimportant native species, or introduced species, often become strongly dominant. The quality of the black bass angling is only one of many criteria to be considered in the evaluation of a reservoir. It has not proven advisable to focus all attention on the maintenance of black bass populations. In Oklahoma, the white bass, white crappie, and channel catfish have been more important to the sportsmen.

Commercial fishing.—Large commercial fishing programs seem to offer the best possibility for the alleviation of overpopulation in large reservoirs. Furthermore, the annual "harvestable" crop of commercial fish from reservoirs of the Southwest could become an important item in the national economy if the means of capture and utilization were developed.

TABLE 1.—*Estimated number of pounds and value of commercial fishes harvested from Denison Reservoir during 1952*

[Data from a Preliminary Report by Houser to the Oklahoma Fish and Game Council]

Species	Pounds	Approximate wholesale value per pound	Percentage by weight	Value
Bigmouth buffalo (<i>Megastomatobus cyprinella</i>)	488,081	\$0.14	64.2	\$ 68,331.34
Carp (<i>Cyprinus carpio</i>)	131,446	0.10	17.3	13,144.60
Flathead catfish (<i>Pilodictis olivaris</i>)	58,952	0.38	7.8	22,401.76
Blue catfish (<i>Ictalurus furcatus</i>)	47,920	0.38	6.3	18,209.60
Gars (<i>Lepisosteus</i> spp.)	19,124	0.05	2.5	956.20
Smallmouth buffalo (<i>Ictiobus bubalus</i>)	5,785	0.14	0.8	809.90
Freshwater drum (<i>Alplodinotus grunniens</i>)	5,650	0.14	0.7	791.00
Carp suckers (<i>Carpiodes</i> spp.)	2,323	0.14	0.3	325.22
Channel catfish (<i>Ictalurus lacustris</i>)	846	0.38	0.1	321.48
Total	760,127	....	....	\$125,291.10

During the last several years, a modest commercial fishing program has been growing on several Tulsa District reservoirs. The estimate in Table 1 indicates the importance of commercial operations on Denison Reservoir during 1952. The harvest rate of a little more than 8 pounds of fish per acre per year represents a small fraction of the annual crop. Rate of harvest comparable to that shown in Table 1 permits partial utilization of a sizable resource, but is not sufficient to prevent further reduction in growth rate of fishes or to benefit the sport species appreciably.

Large commercial fishing programs no doubt can be the basis of an effective management program for reservoirs, since they offer the most feasible single method for controlling fish populations.

NEED FOR PUBLIC EDUCATION

"For a large reservoir . . . the best management recommendations appear to be the encouragement of a maximum harvest of all fishes, which in turn calls for a minimum of regulations and restrictions on the game and pan fishes . . . the application of bag and size limits to fishes which are already abundant and which annually overproduce their environmental

capacities, does not 'save' any fish for anglers but merely deprives fishermen of taking fish that should be harvested for the good of the lake. The problem is one of limiting the number of these prolific fishes to avoid the disastrous effects of over crowding and poor growth" (Hall and Jenkins)¹³.

The above statements by Oklahoma biologists clearly identify the basic management problems of large reservoirs. Realization by the public of the significance of overpopulation, is a prerequisite to the establishment of modern reservoir management. Conservation of fish has long been associated with the familiar evangelistic cry of "protect and conserve our natural resources." As a result, the average fisherman feels it his duty as a good sportsman, to promote the maternal welfare of our fishes. He finds this talk of overpopulation, less emphasis on size and bag limits, and larger commercial fishing programs, hard to understand.

A brief survey around the country reveals that public resistance is today the principal impediment to better management. One of our most difficult problems lies in "conflicts" between commercial- and sport-fishing interests. It will take much public education before a sport fisherman smiles when his outboard motor runs over a gill net; or before he stands by, approvingly, while a commercial fisherman loads a few tons of carp and buffalo. The program will continue to suffer setbacks until the public is thoroughly convinced of the need for seemingly drastic management procedures. Perhaps reservoir management would be served best if we were to exert our major efforts toward public education for the next 10 years. The alleviation of overpopulation and the manipulation of fish populations of a large reservoir are not easy assignments, but can be accomplished if we have the overwhelming weight of public opinion behind the program.

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THE REPRODUCTION OF LAKE TROUT IN SOUTHERN LAKE SUPERIOR

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ABSTRACT

The principal spawning grounds of lake trout (*Salvelinus namaycush namaycush*) in United States waters of southern Lake Superior are on rocky shoals at depths of less than 20 fathoms. Most spawning occurs in October and early November. Of the mature fish collected on or near the spawning grounds, 60 to 69 percent were males. Among mature fish the average length of females was greater than that of males; few males less than 24 inches or females less than 26 inches in total length were caught. Recoveries of lake trout tagged on the spawning grounds showed that some males remained in the immediate area for a period of several weeks during the spawning season. Marked fish showed a tendency to return during later years to spawning grounds on which they had been tagged, even though many of them ranged long distances between spawning seasons.

The percentage of the total weight composed by gonads of maturing females collected in 1950 was 5.0 percent on August 11-30 and 12.3 percent on October 6-9, but this increase was not accompanied by an increase in the coefficient of condition.

One volumetric and two gravimetric methods for estimating numbers of eggs in ovaries were evaluated. Some advantage in accuracy of estimate resulted from the drying of eggs in an oven before weighing on an analytical balance. Production of eggs by 70 lake trout ranging from 25.1 to 38.0 inches in total length and from 5.8 to 19.6 pounds in weight ranged from 2,476 to 17,119. Average production was 646 per pound of fish; this number was greater among fish 31.0 inches long or larger than for fish of smaller size.

Thirteen fish identified by commercial fishermen as siscowets (*Salvelinus namaycush siscowet*) also showed extensive individual variation in numbers of eggs, although egg production tended to increase with increasing length and weight of the fish. A mature female siscowet as small as 16.5 inches long and a 15.7-inch mature male were collected about 45 miles north of Grand Marais, Michigan. Combined data from all collections showed that spawning of lake trout or siscowets may occur during at least 6 months of the year (June to November).

INTRODUCTION

Materials for the study of certain aspects of the reproduction of lake trout in Lake Superior were provided by collections from commercial catches and from experimental gill nets, by recoveries of sexually mature fish which had been tagged on their spawning grounds, and by related field observations, during the years 1950-1954. Although some material from other regions is included, the data are restricted largely to the Marquette-Munising district of south-central Lake Superior. It is believed that this geographical restriction has helped to limit the collections to a single race

or to closely similar races typical of this region, thus avoiding possible confusing effects of physiological differences among the several races of lake trout which are recognized by commercial fishermen (Van Oosten, 1944). Data are added in the last section on reproduction of the siscowet.

Collecting stations and other localities of special interest to which reference is made in the text and tables are shown in Figure 1. Also shown is the boundary of statistical district S-4, one of six geographical areas used in the analysis of commercial fishery statistics of State of Michigan waters of Lake Superior (Hile, Eschmeyer, and Lunger, 1951), within which most of the data were collected.

Some of the field collections on which this paper is based were made by Leo F. Erkkila, in charge of the Marquette, Michigan, station of Great Lakes Fishery Investigations, Fish and Wildlife Service. Joseph Beil, Clifford Tetzloff, and W. S. Glidden assisted in work in the field. Further aid was given by William E. Gladfelter in the laboratory work and by George F. Lunger in the statistical analysis of the data. James W. Moffett and Ralph Hile read the manuscript and offered suggestions. William Cristanelli prepared the illustrations.

SPAWNING GROUNDS AND SEASON

The principal lake trout spawning grounds in United States waters of southern Lake Superior are widely distributed on rocky shoals, at depths of less than 20 fathoms. The main evidence of their location is the concentration in the vicinity of these grounds of sexually mature fish before and during the spawning season, as revealed by increased catches in gill nets of the commercial fishery and the occurrence in these catches of ripe or nearly ripe fish.

There are no published records to date of direct observation of spawning fish in southern Lake Superior, and it is doubtful whether they commonly spawn in water sufficiently shallow to be observed from the surface. Such observations were attempted during two spawning seasons, off Keweenaw Point in October 1950 and near Marquette in October 1953, during periods when the presence of some ripe fish in the general area was shown by their capture in nets. Waters of shoreward areas with rocky bottoms were cruised with a skiff and the bottom observed with a spotlight during evening hours when observations in other waters (Merriman, 1935; Royce, 1951) would indicate that spawning fish might be expected. No lake trout were observed during either year, although a few fish of other species (believed to be round whitefish, *Coregonus cylindraceus*, and burbot, *Lota lota*) were seen in the Marquette area.

In addition to the occurrence of ripe fish in gill-net catches, other evidence of the location of spawning grounds was obtained off Marquette (Station 10, Fig. 1) in March 1953 when 2 recently hatched lake trout (yolk-sac stage) and 1 lake trout egg (in addition to many eggs and fry, presumed to be coregonines, and cottids and invertebrates) were collected during limited use of an apparatus devised for the purpose. This gear

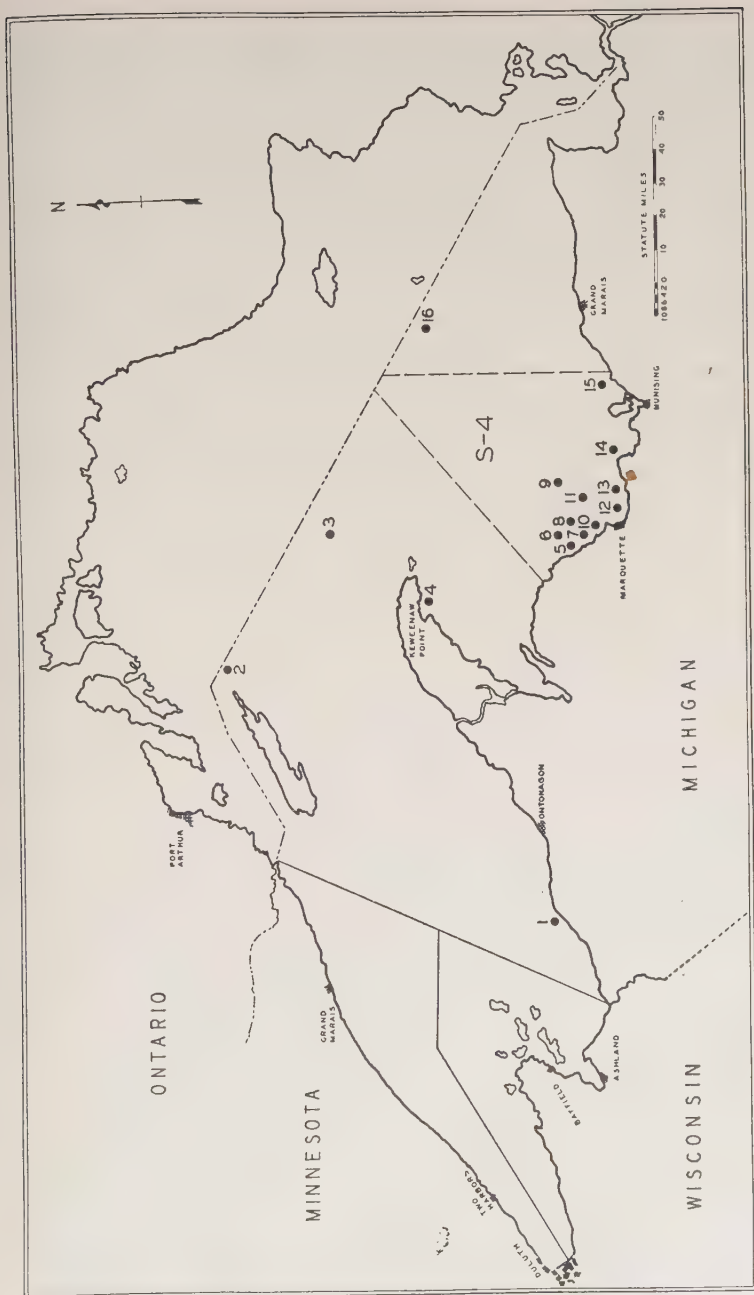


FIGURE 1.—Map of Lake Superior, showing collecting stations and localities of special interest in this study. District S-4 is a geographic area used in the analysis of commercial fishing records for State of Michigan waters of Lake Superior.

consisted of a gasoline-driven centrifugal pump (capacity, 150 gallons per minute) which was equipped with a 2-inch, high-pressure intake hose. One section of the hose extended from the lake bottom to a tightly sealed 50-gallon drum, which acted as a settling tank and in which materials pumped up were screened; a second section of hose led from the tank to the pump. A weighted funnel on the intake end of the hose was moved about over the bottom at various depths in making the collections. The lake trout fry and egg were taken from a depth of 10 fathoms. John Van Oosten (unpublished) used a similar device in 1931 in the collection of 4,410 lake trout eggs in Wisconsin waters of northern Green Bay, Lake Michigan, at depths of 15 to 25 feet. His motive power was the bilge pump of a fishing vessel; a professional diver moved the intake funnel about over the rocky bottom. Rawson and Elsey (1950) reported the recovery (by pumping) of 10 lake trout eggs from spawning grounds of Pyramid Lake, Alberta, at a depth of 10 feet.

In addition to the collection of yolk-sac fry in March 1953, 29 early fingerling lake trout, many of which still had remnants of yolk (range in length, 1.1 to 1.3 inches) were collected by trawling off the extensive Laughing Fish Point spawning grounds (Station 14, Fig. 1) on June 22–23, 1953, at depths of 12 to 16 fathoms. It seems unlikely that these fish had moved far from the hatching locality.

In view of the above observations, it appears that most lake trout in south-central Lake Superior spawn in water considerably deeper than that utilized by the species in certain other lakes. Royce (1951) observed some lake trout spawning in water less than 2 feet deep in Otsego Lake, New York, and Merriman (1935) found spawning to occur in water as shallow as 6 inches in Squam Lake, New York. The detailed descriptions of the courting and spawning behavior of lake trout given by these workers is in good agreement and is probably applicable to that of lake trout of Lake Superior.

The spawning season of lake trout in southern Lake Superior is generally in October and early November. The variation in the season in the Marquette-Munising region (statistical district S-4, Fig. 1) is indicated in Table 1, which summarizes the catch of lake trout in pounds (dressed weight) per thousand feet of large-mesh ($4\frac{1}{2}$ to 7 inches, extension measure) gill net, as reported by commercial fishermen to the Michigan Department of Conservation, for periods immediately preceding and following the closed seasons of 1944–1953. Commercial operators commonly fish on spawning reefs at depths of less than 20 fathoms during much of the period included in the table. Their catches thus undoubtedly reflect major changes in the numerical abundance of lake trout on the spawning grounds, despite possible distorting effects of differences in fishing time between lifts, fluctuations in the average weight of individual fish taken at different times, and probable increased activity of trout near and during the spawning period. Exceptions to this shallow-water fishing occur in the period November 10–14, when, if the first lifts reveal no concentrations of fish on the spawning grounds, nets are moved to deeper

waters. In 1951, for example, the increase in catches on November 10-14 over November 5-9 presumably did not represent a resurgence of spawning activity, but a movement of the fishery to deep water, where good catches are sometimes made during this season of the year. To limit the data to the spawning-run fishery, deep-water lifts were deleted from the data when they were recognized; however, the exact fishing locality could not always be determined from the fishermen's reports.

The record of commercial catches shows that the greatest concentration of fish occurred before the closed season in 3 years (1944, 1951, and 1952) and after the closed season in 5 (1945, 1947, 1949, 1950, and 1953). In two seasons (1946 and 1948) nearly all spawning presumably occurred within the closed season prescribed by law as there was little indication of a marked concentration of fish either before or after it. For the 10-year period included in Table 1, the weight of the catch per unit of gear during the 5-day period before or after the closed season (whichever was larger) averaged 2.6 times greater (range, 1.4 in 1946 to 4.9 in 1951) than the average catch for the entire season. These values do

TABLE 1.—*Production of lake trout (pounds per thousand feet of gill net) preceding and following the closed season in the Marquette-Munising district of Lake Superior, 1944-1953*
[Number of thousands of feet of gill net are shown in parentheses. The closed season extended from October 10 to November 4.]

Year	September		October		November		Average for entire year ¹
	21-25	26-30	1-5	6-10	5-9	10-14	
1944.....	13.4 (489)	17.7 (680)	24.5 (492)	34.3 (460)	13.9 (158)	16.3 (95)	16.2
1945.....	18.2 (492)	17.4 (550)	22.1 (590)	21.1 (447)	42.8 (70)	23.8 (51)	17.6
1946.....	12.5 (830)	20.8 (832)	17.5 (1,193)	19.5 (865)	16.3 (249)	15.1 (414)	13.9
1947.....	14.9 (368)	18.3 (519)	19.1 (533)	24.0 (684)	48.6 (481)	28.2 (248)	16.0
1948.....	14.0 (735)	13.2 (694)	20.4 (762)	19.5 (940)	14.5 (234)	11.8 (192)	11.7
1949.....	15.1 (650)	15.4 (874)	11.9 (921)	11.0 (1,041)	29.3 (384)	14.6 (232)	11.6
1950.....	13.1 (848)	12.9 (1,218)	26.2 (836)	30.7 (1,062)	37.2 (785)	28.3 (336)	14.2
1951.....	20.3 (793)	29.1 (644)	28.9 (942)	74.0 (674)	13.5 (241)	19.0 (276)	15.0
1952.....	14.6 (1,036)	18.5 (666)	26.0 (705)	33.9 (1,129)	17.8 (325)	14.8 (301)	14.0
1953.....	19.7 (968)	18.9 (714)	18.8 (946)	?	35.0 (510)	26.0 (432)	12.1

¹ Averages for years 1944-1949 from Hile, Eschmeyer, and Lunger (1951); data for years 1950-1953 unpublished
² Closed season was advanced 5 days in 1953 to begin at noon on October 5

not imply, however, that more than $2\frac{1}{2}$ times as many individuals were caught during these periods, because the fish taken in large-mesh gill nets before and after the closed season often average more than double the weight of fish taken at other times during the year.¹

In 1952 and 1953 the greatest concentration of lake trout on the spawning grounds undoubtedly occurred during the closed season, despite good commercial catches before or after. A total of 4,800 feet of large-mesh gill net lifted on spawning grounds near Marquette October 18–31, 1952, and 25,200 feet lifted October 17–23, 1953, caught lake trout at estimated rates of 157 and 65 pounds (dressed weight), respectively, per thousand feet of net, or 4.6 and 1.9 times the highest rate of capture in commercial nets lifted before (1952) or after (1953) the closed season.

SEX RATIO, LENGTH-FREQUENCIES, AND SIZE AT FIRST MATURITY

Among sexually mature lake trout caught in the Marquette-Munising district on or near the spawning grounds during or preceding the spawning season, males outnumbered females in collections made in 1950, 1952, and 1953 (Table 2). The percentages of males were 60.2 on September 26–October 9, 1950; 66.1 on November 8, 1950; 65.1 on October 18–31, 1952; and 69.3 on October 17–23, 1953. The percentages of males given for the 1952 and 1953 collections are minimal because the fish were not dissected and the sex was not determined for 13 taken in 1952 and for

TABLE 2.—Length-frequency distribution of sexually mature lake trout collected in gill nets on or near spawning grounds in the Marquette-Munising region of Lake Superior

Total length (inches)	Date of collection and sex									
	September 26– October 9, 1950		November 8, 1950		October 18–31, 1952 ¹		October 17–23, 1953 ²		Total	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
22.0–23.9.....	..	..	..	..	..	..	2	..	2	..
24.0–25.9.....	6	..	2	..	6	1	7	..	21	1
26.0–27.9.....	15	3	6	1	20	5	26	5	67	14
28.0–29.9.....	26	19	18	7	22	10	37	7	103	43
30.0–31.9.....	18	12	26	9	12	4	40	18	96	43
32.0–33.9.....	6	9	11	8	8	2	25	12	50	31
34.0–35.9.....	5	10	6	6	3	3	12	5	26	24
36.0–37.9.....	3	..	5	3	..	..	2	1	10	4
38.0–39.9.....	1	..	..	1	..	..	..	..	1	1
40.0–41.9.....	..	..	..	3	..	..	..	..	..	3
Average length.....	29.9	31.0	30.9	32.8	29.1	29.8	30.1	31.3	30.0	31.3
Number of fish.....	80	53	74	38	71	25	151	48	376	164

¹ Thirteen fish of undetermined sex not included

² Nineteen fish of undetermined sex not included

¹ In representative collections made in the vicinity of Marquette, 377 legal lake trout occurring in five collections taken in $\frac{1}{2}$ -inch-mesh gill nets between June 2 and August 30, 1950, averaged 3.4 pounds in round weight (range of averages in the five collections, 3.1 to 3.6 pounds). A total of 208 legal fish, taken in $\frac{1}{2}$ - and 6-inch-mesh gill nets in the same vicinity September 26–November 8, 1950, averaged 8.7 pounds in round weight (range of averages in the three collections, 8.2 to 9.5). In Michigan the minimum legal size is $1\frac{1}{2}$ pounds.

19 in 1953. (Although most of these fish were believed to be green females, some may have been immature fish or mature males which were not yet ripe). In the combined collections, males made up 65.7 percent of the total.

Males also predominated in collections of spawning lake trout in other waters. Royce (1936) wrote that in spawn-taking operations in New York there were "about two males for each female," and the New York Conservation Department (1944) reported 77 and 78 percent males among lake trout examined during spawn-taking operations in Seneca Lake, New York, in 1941 and 1942. Miller and Kennedy (1948) found that 75 of 87 (86 percent) of the mature fish collected from a spawning run in Great Bear Lake were males. It is not known whether collections at these localities and in Lake Superior indicate a greater number of male lake trout on the spawning grounds, or whether they reflect greater activity by males than by females during the spawning season, since all fish were collected in stationary nets.

The total lengths of sexually mature male lake trout collected in large-mesh gill nets set on or near the spawning grounds in the Marquette-Munising region of Lake Superior ranged from 22.3 to 38.2 inches (average, 30.0), and lengths of females from 25.8 to 40.4 inches (average, 31.3). Although the sizes of mesh² used undoubtedly influenced the size of fish caught, males in all collections had a smaller average length than females, began maturing at smaller size, and were better represented among the smaller length classes than among fish of large size. For example, in the combined collections of September 26–October 9, 1950, (early in the spawning season) males composed 66 percent of the fish less than 32 inches in length and only 44 percent of the trout 32 inches long or longer; on November 8 (late in the spawning season) these percentages were 75 and 51 percent, respectively.

The available data on length of lake trout at maturity (Table 3) are not fully satisfactory since relatively few large fish were present in the collections outside the spawning season and the pre-spawning and spawning-run collections may have been biased toward overrepresentation of mature individuals³. Scanty and defective as the records may be, they give strong evidence that lake trout of both sexes first reach maturity at a relatively great size and that males become mature at a smaller length than do females. The shortest mature male in the non-spawning samples was 25 inches (lower limit of 1-inch interval), but the spawning collections included mature males as short as 22 inches. No mature females less than 25 inches long were in either group. The largest immature males were in the 29-inch class in both non-spawning and spawning samples, as was the largest immature female of the non-spawning collections. The spawning-run samples, however, included 5 larger immature females, 4 in the 30-

² The sizes of mesh in inches (extension measure) of gill nets used in the collections were as follows: September 26–October 9 and November 8, 1950—5½ and 6; October 18–31, 1952, 5½; and October 17–23, 1953—4½, 5, 5½, and 6.

³ Data were restricted to collections in which the sex of all fish caught was determined by dissection, at a season when evaluation of maturity of the gonads was presumed to be unquestionable.

TABLE 3.—*Length-frequency distribution, sex, and maturity of lake trout collected in southern Lake Superior, July 25–December 21, 1950*

Total length (inches)	Non-spawning ¹						Spawning ²			
	Males			Females			Males		Females	
	Immature	Mature	Percent-age mature	Immature	Mature	Percent-age mature	Immature	Mature	Immature	Percent-age mature
<22.0.....	157	..	0	134	..	0	121	..	82	0
22.0-22.9.....	19	..	0	28	..	0	5	2	7	0
23.0-23.9.....	14	..	0	17	..	0	5	1	3	0
24.0-24.9.....	6	..	0	6	..	0	2	9	3	0
25.0-25.9.....	6	1	14	4	1	20	1	11	4	43
26.0-26.9.....	2	2	50	4	1	20	..	17	6	5
27.0-27.9.....	1	..	0	1	1	50	1	24	7	45
28.0-28.9.....	1	1	50	..	..	..	..	32	5	59
29.0-29.9.....	2	..	0	1	1	50	1	26	4	84
30.0-30.9.....	..	1	100	..	1	100	..	29	4	82
31.0-31.9.....	..	..	..	..	..	..	..	30	1	87
>31.9.....	..	..	..	..	1	100	..	44	..	100
Total.....	208	5	2	195	6	3	136	225	126	55

¹ Collected July 25, August 11, 17, 30, November 22, December 12, 14, 21 in 4½-inch-mesh (extension measure) gill nets off Keweenaw Point, Marquette, and Munising² Collected September 8, 9, 12, 16, 20, 26, 29, October 9, November 8 in 4½-, 5½-, and 6-inch-mesh gill nets off Ontonagon, Keweenaw Point, Marquette, and Munising

inch and 1 in the 31-inch interval. If the mean between the smallest mature and the largest immature fish is accepted as a rough estimate of average size at first maturity, the following figures are obtained: males, 25½ inches; females, 28 inches.

The possibility remains that some of the larger immature fish may have spawned earlier in life, even though their reproductive organs did not mature during the year of collection. The numbers of immature fish tended to diminish progressively with increasing size, however, and no immature fish were found among 57 females and 44 males with total lengths of 32 inches or more. No gonads were seen which conformed to Kennedy's (1954) description of the gonads of mature non-spawning lake trout collected in Great Slave Lake. Such "infecund" fish of large size were also observed among lake trout in certain other waters (Fry and Kennedy, 1937; Fry, 1949; Miller and Kennedy, 1948).

The observations on size at sexual maturity of lake trout in Lake Superior conform closely to the findings of Dymond (1928), who reported that female lake trout in the western end of Lake Ontario do not begin to spawn until they reach a weight of approximately 6 pounds (equivalent to a length of about 26½ inches in Lake Superior fish), and of Royce (1951) who wrote that lake trout in Seneca Lake, New York, do not mature until they are 26 to 30 inches in total length. In contrast, lake trout in a number of Canadian waters may become mature at lengths ranging between 14 and 18 inches (Fry, 1939; Miller and Kennedy, 1948; Kennedy, 1954). Sexual maturity at lengths of 15 to 16 inches was also reported in Skaneateles Lake, New York (Royce, 1951, referring to unpublished data of H. J. Rayner), and some siscowets collected in Lake Superior, about 45 miles north of Grand Marais, Michigan, were mature at similar lengths (p. 69).

MOVEMENT ON THE SPAWNING GROUNDS AND HOMING BEHAVIOR

Some male lake trout apparently remain on or near the spawning grounds several weeks during the spawning season. This behavior was indicated by recoveries of marked fish in the commercial fishery following the tagging of 187 large lake trout (average total length, 30.1 inches; range, 22.3–36.5) during the period October 17–23, 1953, on spawning grounds near Marquette (Stations 5, 7, 10, and 14, Fig. 1). Of this group, 132 were males and 36 were females; the sex of 19 was not determined. Later recoveries, 18 to 26 days after marking, included 9 males and 1 fish of unknown sex, all caught within 8 miles of the place of release, on the same or a contiguous spawning area. Three males and 1 fish of unknown sex were recovered during the same period at distances of 26 to 97 miles, but in shallow water at localities recognized by commercial fishermen as lake trout spawning grounds. These fish apparently had moved to other breeding areas during the spawning season. One male was caught 34 days after tagging, in deep water (60 fathoms), 37 miles from the place of release.

Although some fish apparently remained near the spawning grounds during other seasons of the year (1 recovery in April, 1 in May, and 1 in July 1954, all within 5 miles of the locality of release), others dispersed widely. Eight recaptures during the period December 10, 1953-September 9, 1954, were at distances of 14 to 189 miles (average, 54) from the place of release.

Later recoveries, as fish again started to move toward their spawning grounds, corroborated strongly the conjecture of Eschmeyer, Daly, and Erkkila (1953) that, although large lake trout in Lake Superior dispersed widely through the lake after spawning, some (perhaps many or most) returned to their established spawning grounds during subsequent spawning seasons. Twelve of 14 recoveries made between September 23 and November 12, 1954, from the lake trout tagged on the spawning grounds near Marquette in October 1953 were within 8 miles of the place of release, at depths of less than 25 fathoms. One fish was caught on different spawning grounds 28 miles away, and another, which had probably finished spawning, was taken at 65 fathoms, 34 miles from the tagging locality.

Additional evidence on the movement of lake trout following spawning resulted from the tagging of 96 large fish (average total length, 29.5 inches; range, 24.3 to 35.8) on spawning grounds near Marquette (Station 10, Fig. 1), October 18-31, 1952. After 10 recoveries between November 13, 1952, and September 11, 1953, at distances ranging from 13 to 198 miles (average, 71), 12 lake trout were recaptured near or during the subsequent spawning season, September 14-November 10, 1953, within 8 miles of the tagging locality. During this same period, however, 5 fish were captured on other spawning reefs 18 to 62 miles away. Six later recoveries, April 6-July 7, 1954, were 23 to 120 miles (average, 78) from the tagging locality, although 5 fish caught between August 9 and September 9, 1954, were within 5 miles of the place of release. One tagged trout was recaptured on October 2, 1954, on a reef 27 miles from the tagging locality and 3 of 4 recoveries on November 5-9, immediately following the closed season, were within 8 miles of the place of release; the other was on a reef 21 miles away.

Eschmeyer, Daly, and Erkkila (1953) listed 7 recoveries during the period September 10-October 9, 1952, from 116 large lake trout tagged off Keweenaw Point (Station 4, Fig. 1) on October 11-27, 1950. Six of these recaptures were within a radius of about 20 miles from the tagging locality and 1 was 140 miles away. Two recoveries from this group of fish, on September 14, 1953, and September 30, 1954, were within 8 miles of the tagging locality. One fish was caught on other spawning grounds (November 6, 1953), 55 miles from the place of release.

A precise conclusion as to the homing tendencies of spawning lake trout is made difficult by the fact that a fish captured and tagged or recaptured in a particular spawning area may not in fact be on its "home" ground, but rather may be enroute to or from it. Although all spawning lake trout possibly may exhibit homing behavior, available evidence

permits only the statement that the tagged individuals showed a proclivity to return during later years to spawning grounds on which they had been marked, even though many of them ranged long distances between spawning seasons. The recoveries from the two experiments (1952 and 1953) in the Marquette area indicate that 27 of 36 (75 percent) tagged fish recovered near or during spawning seasons subsequent to that of tagging were caught on the spawning grounds on which they were released.

DEVELOPMENT OF THE GONADS

The ovaries of lake trout—paired, elongated organs suspended near the dorsal side of the body cavity, beneath the air bladder—conform in most details to the description of ovaries of salmonoid fishes given by Kendall (1921).

The left ovary was usually the heavier in mature fish collected in southern Lake Superior August 11–November 8, 1950, and August 27–October 10, 1951. In 64 lake trout whose left and right ovaries were weighed separately, the left was heavier in 72 percent, lighter in 16 percent, and in 12 percent the two ovaries were of about equal weight (difference less than 5 percent). For all fish the weight of the right ovary averaged 86 percent of the weight of the left. The size of eggs was the same in ovaries of unequal weight but the numbers differed according to the difference in weight. The heavier ovary had the larger number of eggs in all 28 of the fish for which estimates or counts of egg numbers were made separately for each ovary and in which ovary weights differed by as much as 5 percent.

Differences between the size of right and left male gonads were sometimes apparent upon dissection, although few were weighed separately. Of 5 mature males collected on October 18, 1952, the testes were of about equal weight (difference less than 5 percent) in 2 fish; in the other 3 the weights of the right testes equalled 9, 74, and 83 percent of the weights of the larger left testes. The first of the three values is extreme, and may have been the result of partial atrophy or disease of the one organ.

The weights of male and female gonads, expressed as percentage of the total weight of lake trout, preceding, during, and following the spawning season of 1950, are shown in Table 4. Average diameters (determined by use of an egg-measuring trough) of the eggs in samples of 50, taken at random from the ovaries of sexually mature females, are also shown.

Most gonads were preserved in 10-percent formalin. They were weighed after removal of excess liquid from the surface by blotting. The effect of preservation on the estimation of weight was determined by comparisons of weights of gonads in both the fresh and preserved condition for 14 mature males, 3 immature females, and 6 maturing females. These comparisons indicated the following factors for conversion from preserved to fresh weights: mature males, 1.176; immature females, 1.073 (value used also for spent females and immature males); and ripening females, 1.034. Although these conversion factors are based on limited data, they are

TABLE 4.—Percentage of total weight composed by gonads of lake trout in southern Lake Superior, 1950
[Numbers of fish in parentheses]

Sex, maturity, and date of collection	Total length (inches)							Average diameter of eggs (millimeters)
	12.0-15.9	16.0-19.9	20.0-23.9	24.0-27.9	28.0-31.9	32.0-35.9	36.0-39.9	
Immature females								
September 8—November 22.....	0.1 (11)	0.1 (19)	0.2 (21)	0.5 (12)	0.6 (5)	...	...	...
Mature females								
August 11-30.....	...	...	...	5.6 (1)	4.7 (2)	...	...	3.7 (3)
September 8-9.....	...	...	...	7.2 (4)	6.8 (13)	8.5 (3)	...	7.1 (20)
September 16-29.....	...	...	...	9.3 (8)	9.6 (18)	11.8 (7)	...	10.0 (33)
October 6-9.....	...	...	...	11.2 (2)	11.8 (16)	13.3 (9)	...	4.9 (27)
November 8.....	...	...	...	12.9 (1)	11.7 (1)	...	...	5.1 (25)
November 8 ¹	...	...	...	...	1.7 (11)	1.9 (12)	...	1.3 (23)
Immature males								
September 8-20.....	0.1 (9)	0.1 (13)	0.1 (19)	0.1 (1)	0.1 (1)	...	...	...
Mature males								
September 8-9.....	...	...	3.2 (1)	2.7 (7)	2.4 (18)	4.5 (1)	...	...
September 16.....	...	...	2.6 (3)	2.9 (18)	3.7 (2)	4.8 (1)	3.9 (1)	...
November 8.....	...	...	...	2.0 (4)	1.5 (19)	1.9 (11)	2.9 (1)	...

¹ Ripe or nearly spent ovaries from which residual mature eggs were removed before weighing. The average egg diameter is for the larger of two size groups of immature eggs remaining in the ovaries

believed to represent an improvement over unconverted preserved weights.

The weight of the ovaries equalled only 0.1 percent of the total weight of immature females less than 20 inches long. For fish of larger size this percentage increased progressively from 0.2 percent in fish 20.0 to 23.9 inches long to 0.6 percent for fish in the 28.0- to 31.9-inch group. Immature males did not show this increase. The testes made up 0.1 percent of the total weight in each of the five length groups over the range of 12.0–31.9 inches.

The ovaries of mature females composed a progressively greater percentage of the body weight as the spawning season approached. The average percentages were: 5.0 on August 11–30; 7.1 on September 8–9; 10.0 on September 16–29; and 12.3 for fish collected near the time of spawning (October 6–9 and November 8 collections combined). For ripe or nearly spent fish collected on November 8, the weight of the ovary, after removal of all remaining mature eggs, was equal to 1.8 percent of the total weight of the fish.

A trend toward an increase in the percentage of total weight composed by the reproductive organs with an increase in the size of fish was demonstrated by data for the two largest collections of females with maturing ovaries. For collections of September 16–29, this percentage increased from 9.3 percent for fish in the 24.0- to 27.9-inch group to 11.8 percent for fish in the 32.0- to 35.9-inch class. In the October 6–9 collections values for these same groups were 11.2 and 13.3 percent, respectively. As might be expected, this increase was associated with an increase in egg production per pound of fish among larger individuals (Table 8). A progressive increase in the average diameter of the eggs, from 3.7 millimeters (range, 3.2–4.1) in fish taken August 11–30 to 5.1 millimeters (range, 4.6–5.7) in fish collected on November 8, was associated with the increase in weight of the ovaries with the progress of the season. (No correlation was observed between the diameter of the eggs and the size of the fish within the range of lengths of fish examined.) The larger immature eggs remaining in ovaries of ripe or nearly spent lake trout collected on November 8 had an average diameter of 1.3 millimeters.

The weights of the gonads of mature males collected September 8–9, 1950, averaged 2.6 percent of the total weight of the fish. On September 16 this percentage was 3.1. By November 8, late in the spawning season, depletion of the gonads had progressed to the stage where their weight averaged only 1.7 percent of the total weight.

The proportion of the total weight made up by gonads of lake trout collected in the Marquette-Munising district of Lake Superior in 1951–1953 (Table 5) shows the same progressive increase with progress of the season demonstrated by the 1950 data of Table 4. The average proportion of the total weight composed by the ovaries and the average diameter of the eggs of 2 large females examined on May 16, 1951, were about the same as for spent females collected November 8, 1950, and for spent fish collected October 19–23, 1953. This agreement suggests that the increase in weight of the ovaries accompanying development of eggs for fall

TABLE 5.—Percentage of total weight composed by gonads of mature lake trout in southern Lake Superior, 1951-1953

[Numbers of fish in parentheses]

Sex and date of collection	Total length (inches)						Average diameter of eggs (millimeters)
	20.0-23.9	24.0-27.9	28.0-31.9	32.0-35.9	36.0-41.0	Average	
Females							
May 16, 1951.....	...	...	...	...	1.6 (2)	1.6 (2)	1.6 (2)
July 22, 1953.....	...	2.7 (2)	...	6.0 (1)	...	3.8 (3)	3.3 (3)
August 20-27, 1951.....	...	7.8 (3)	8.5 (6)	6.9 (1)	...	8.1 (10)	4.4 (10)
October 8-10, 1951.....	...	10.2 (1)	16.9 (6)	15.7 (6)	16.8 (2)	16.0 (15)	5.2 (15)
October 17-20, 1953.....	...	17.3 (1)	...	17.7 (3)	22.0 (1)	18.5 (5)	5.4 (1)
October 19-23, 1953 ¹	...	...	1.7 (5)	1.9 (1)	...	1.7 (6)	...
Males							
May 16, 1951.....	...	...	...	...	0.7 (2)	0.7 (2)	...
June 17, 1953.....	...	1.5 (2)	...	...	...	1.5 (2)	...
July 22, 1953.....	1.2 (1)	0.8 (1)	0.9 (2)	...	...	1.0 (4)	...
September 29, 1953.....	2.3 (1)	...	...	...	...	2.3 (1)	...
October 18, 1952.....	...	2.1 (1)	2.5 (4)	...	...	2.4 (5)	...
October 17-23, 1953.....	2.1 (1)	2.2 (2)	3.1 (13)	3.7 (4)	...	3.1 (20)	...

¹ Spent or ripe ovaries from which residual mature eggs were removed before weighing

spawning had not yet begun. This increase was well underway in 3 fish collected July 22, 1953, whose gonads averaged 3.8 percent of the total weight (average egg diameter, 3.3 millimeters). On August 20-27, 1951, the percentage was 8.1 (egg diameter, 4.4 millimeters). The relative weight had nearly doubled, to 16.0 percent (egg diameter, 5.2 millimeters) by October 8-10 of that year; and for 5 fish collected October 17-20, 1953, the percentage was 18.5. Thus the limited number of ovaries of maturing females collected in 1951 and 1953 made up a somewhat higher percentage of the weight of the fish than they did in lake trout taken on comparable dates in 1950 (Table 4). The range of variation was wide, however, and a larger series of specimens would be required to detect

significant annual differences, or to corroborate for southern Lake Superior Fry's (1949) observation in Lake Opeongo, Ontario, that average egg production (presumably closely related to weight of the ovary) of lake trout of all ages may be consistently above or below average during some years.

Few testes were weighed during 1951–1953, but the limited data suggest an irregular increase in weight during the season, from 0.7 percent of the total weight in 2 large males collected on May 16, 1951, to 3.1 percent for fish collected October 17–23, 1953. In all samples (1950–1953) the weight of the testes of mature males exceeded 5 percent of the total weight in only 1 fish (collected September 16, 1950).

For both males and females in the several collections the proportional weight of the gonads of immature fish (collected September 8–November 22, 1950) was smaller than that of spent mature fish. For individual mature fish the minima observed were 0.7 percent for males and 1.1 percent for females; for immature fish of the 1950 collections the maximum weights of the gonads equalled 0.2 percent for males and 0.8 percent for females.

RELATIONSHIP OF CONDITION TO SPAWNING

The coefficient of condition C^4 (Table 6) for three 4-inch length groups of mature lake trout collected in 1950 indicates that within the length range of 24.0–35.9 inches condition did not change consistently with length and that the average values for all fish (right-hand column) were in reasonably good agreement with those for fish of each 4-inch length class. A progressive increase in the condition of females with the approach of the spawning season was not indicated, despite the progressive increase already mentioned in the proportion of the total weight composed by the ovaries. In collections represented by 20 or more fish C was 34.4 on September 8–9, 35.1 on September 16–29, and 33.8 on October 6–9.⁵ This value diminished to 29.3 as an average for 23 spawning fish (9 to 3,750 mature eggs in their ovaries) collected on November 8. When the weight of the residual eggs was deducted from the weight of each fish and the C value recomputed, this average (applying then to fully spent females) was 28.9.

The failure of female lake trout to improve in condition although an increasing percentage of the total weight was being contributed by the gonads is clearly indicative of a decrease in body condition (when considered exclusive of gonads). The nature of this decrease is shown more clearly when the condition factor is computed after the weight of the gonads has been deducted from the total weight of the fish (here termed the "basic" condition factor). The resulting values declined progressively

$C = \frac{W \cdot 10^5}{L^3}$ where W = weight in pounds and L = total length in inches.

⁵ Two other fall-spawning Great Lakes species exhibited a decline in the condition of mature fish prior to the spawning season, the kiyi of Lake Michigan (Deason and Hile, 1947) and the whitefish of Lake Erie (Van Oosten and Hile, 1949).

TABLE 6.—Condition factors (C) of lake trout collected in southern Lake Superior, 1950
[Numbers of fish in parentheses]

Sex and date of collection	Type of condition factor ¹	Total length (inches)			
		24.0-27.9	28.0-31.9	32.0-35.9	Average
Females					
August 11-30.....	<i>C</i>	33.1	33.2	....	33.2
	Basic <i>C</i>	31.2	31.7	....	31.5
		(1)	(2)		(3)
September 8-9.....	<i>C</i>	33.3	34.0	37.3	34.4
	Basic <i>C</i>	30.9	31.7	34.2	31.9
		(4)	(13)	(3)	(20)
September 16-29.....	<i>C</i>	35.8	34.3	36.5	35.1
	Basic <i>C</i>	32.5	31.1	32.2	31.7
		(8)	(18)	(7)	(33)
October 6-9.....	<i>C</i>	34.4	33.7	33.8	33.8
	Basic <i>C</i>	30.5	29.8	29.3	29.7
		(2)	(16)	(9)	(27)
November 8.....	<i>C</i>	35.6	31.3	....	33.4
	Basic <i>C</i>	31.0	27.7	....	29.4
		(1)	(1)		(2)
November 8 ²	<i>C</i>	....	29.4	28.5	28.9
	Basic <i>C</i>	....	28.9	27.9	28.4
				(11)	(12)	(23)
Males					
September 8-9.....	<i>C</i>	32.6	33.5	39.6	33.5
	Basic <i>C</i>	31.7	32.7	37.8	32.6
		(7)	(18)	(1)	(26)
September 16.....	<i>C</i>	33.8	33.0	36.2	33.9
	Basic <i>C</i>	32.8	31.7	34.4	32.8
		(18)	(2)	(2)	(22)
October 6-9 ³	<i>C</i>	30.6	31.2	35.0	31.1
		(9)	(21)	(1)	(31)
November 8.....	<i>C</i>	28.2	32.0	30.5	31.0
	Basic <i>C</i>	27.6	31.5	29.9	30.5
		(4)	(19)	(11)	(34)

¹ Basic C refers to the condition factor computed after deduction of the weight of the gonads from the weight of the fish

² Spent or ripe fish from which weight of residual mature eggs was deducted before computation of C

³ The testes of fish of this collection were not weighed

for fish in collections made between September 8-9 and November 8. The greatest rate of decline was between the September 16-29 and October 6-9 collections, when the average coefficient diminished from 31.7 to 29.7; it declined further to 28.4 for ripe and spent fish collected November 8.

The decline in basic condition with the increase in percentage of total weight composed by the gonads can also be demonstrated in the collection of October 6-9, considered alone. In fish of this collection, the basic condition factor and the percentage of the body weight composed by gonads showed a negative correlation ($r = -0.397$; $p < 0.05$)⁶.

⁶ Length of fish and basic condition showed no correlation.

Basic condition factors of maturing females collected in other years were in close agreement with those of fish caught on comparable dates in 1950. Females collected August 20-27, 1951, had an average basic condition factor of 31.6; the factor on October 8-10 was 29.8 (comparable 1950 values were 31.6 and 29.6). Five nearly ripe females captured October 17-20, 1953, had an average basic factor of 29.6.

Among mature males collected in 1950, changes in condition related to spawning were not usually as great as for females collected during the same year, although they reflected the same drop in condition shown by the females between the September and October collections. The condition factors (whole fish) of males averaged 33.7 on September 8-16 and 31.1 on October 6-9. Basic condition was 32.7 for the September 8-16 fish and 30.5 for fish collected November 8. Basic factors are not available for collections between these dates during 1950, but the factors for males collected October 18, 1952, and October 17-23, 1953, had the intermediate values of 31.8 and 32.2, respectively.

Although whole-fish condition factors of males were lower than those of females taken at comparable dates during the period September 8-October 9, the condition of males was better than that of spawning and spent females on November 8, toward the end of the spawning season. The basic condition factor of males was higher than that of females in all comparable collections.

The loss of condition prior to spawning may have been related in part to a reduction in the amount of food eaten as the spawning season neared. Although Martin (1949) noted that lake trout fed throughout the spawning period, Miller and Kennedy (1948) found that 69 percent of the stomachs of 87 mature lake trout caught early in the spawning season in Great Bear Lake were empty; stomachs of the others were nearly empty. Observations in southern Lake Superior indicated that feeding was markedly reduced near the time of spawning. Of 85 mature fish whose stomachs were examined on November 8, 1950, when nearly all fish were ripe, 76 (89 percent) were empty (stomachs of each of 3 immature fish taken in the same nets contained food). Of 32 fish (4 green, 28 ripe) examined October 17-23, 1953, 31 (97 percent) contained no food. This situation is in contrast to collections on September 8, 1950, when stomachs of only 10 of 43 mature fish (23 percent) were empty, and on September 16, 1950, when 28 of 52 (54 percent) contained no food. (Fishing time of the nets presumably tended to minimize rather than to increase this seasonal difference, since nets lifted in September had been out 4 to 7 nights, whereas nets lifted in November 1950 and October 1953 had been out for shorter periods). It is not known whether the difference in percentage of empty stomachs on September 8 and on September 16 are indicative of a progressive decline in feeding activity (no information for intermediate collections). However, the data strongly suggest that feeding had diminished pronouncedly by the time of spawning.⁷

⁷ Limited data available indicated that the physical absence or presence of food in stomachs at the time of collection did not in itself materially affect the estimate of average basic condition.

FECUNDITY

Of 79 lake trout ovaries for which egg counts or estimates were made, 59 were collected in the Marquette-Munising district of Lake Superior, 13 west of Ontonagon, Michigan (Station 1, Fig. 1), and 7 near Keweenaw Point (Station 4). The fish were caught in large-mesh commercial or experimental gill nets (73), or pound nets (6). Of the total, 69 were taken August 18-November 8, 1950, 9 were collected August 27-October 10, 1951, and 1 on October 18, 1953.

Methods of estimating egg numbers.—One volumetric and two gravimetric methods for estimating numbers of eggs in ovaries were evaluated. In all three methods, eggs in measured samples of the ovary were counted and the numbers of eggs in the remainder estimated by direct proportion. Accuracy of estimates was determined by complete counts.

In the volumetric method the eggs in a sample and the eggs in the remainder of the ovary were measured by water displacement in a graduated cylinder. In the first of the gravimetric methods, excess liquid was blotted from the surface of the ovary and the eggs in a sample and the eggs in the remainder of the ovary were weighed on a triple-beam balance (graduated to 0.1 gram). For both the volumetric and the wet-weight methods as many as six samples on which estimates were based were taken from the ovaries of a single fish, from various loci (*e. g.*, anterior, middle, and posterior portions of the left and the right ovary). Estimates used in the tests were restricted to the ovary from which the sample was taken, although the size of the nearly mature eggs did not differ significantly between ovaries of the same fish or between various parts of the same ovary.

In the second or dry-weight gravimetric method the preserved ovaries were broken into sections and the eggs separated from much of the ovarian tissue by rubbing between the hands. The eggs were then placed in shallow pans or in bags of loosely woven cloth and put on the shelves of a drying oven, where they were left (with oven ventilators open) at a temperature of about 80° to 90° C. for 2 to 6 hours. During this period the eggs were stirred or turned occasionally to facilitate uniform drying. After the drying, random samples of eggs and the remainder of the eggs in the lot were weighed on an analytical balance. Estimates were made only for the eggs of an ovary or ovaries dried in a single pan or bag, because drying was seldom exactly uniform among the eggs in different containers, even though they were from the same fish. In testing the method, five samples of 100 dried eggs each were weighed from an ovary or ovaries of each of 17 fish.

The volumetric method was poorer than either of the gravimetric methods for estimating numbers of eggs in lake trout ovaries (Table 7). The percentage error of the estimates covered a wider range and the mean deviation (average of absolute values of percentage error) was greater (3.2 percent) in the volumetric than in the gravimetric methods. Only 17 percent of the samples gave estimates with an error of less than 1 percent.

In the wet-weight method of estimation the range in percentage error of estimates was less and the mean percentage deviation was markedly lower (1.9) than in the volumetric method. Forty-five percent of the samples gave an error of estimate of less than 1 percent.

Estimates by the dry-weight method had the smallest range in error and had the smallest mean deviation (0.7 percent) of the three methods tested. For 85 100-egg samples the percentage error of estimate ranged from -4.7 to 3.2 (average, -0.3) and the mean deviation was 0.7 percent; 51 percent of the samples gave an error of estimate of less than 1 percent. This greater accuracy was obtained even though the 100-egg

TABLE 7.—Comparison of three methods of estimating numbers of eggs in lake trout ovaries

Number of samples	Percentage of total eggs in sample		Percentage error of estimates		Mean percentage deviation ¹	Percentage of estimates with less than 1.0 percent error
	Range	Average	Range	Average		
Volume 24.....	8.0-24.9	15.0	-6.0 to 8.5	1.7	3.2	17
Wet weight 29.....	8.0-24.9	15.1	-5.1 to 4.6	-0.7	1.9	45
Dry weight 85 ²	1.0- 7.7	4.3	-4.7 to 3.2	-0.3	0.7	51
17 ³	4.9-38.5	21.3	-2.2 to 1.2	-0.3	0.7	65

¹ Average of absolute values

² Samples of 100 eggs

³ Samples of 500 eggs

samples composed an average of only 4.3 percent of the total number of eggs in the ovaries, as compared to 15.0 and 15.1 percent in the tests of the volumetric and wet-weight methods. When five 100-egg samples were combined as a single estimate for each of the 17 fish, the range of the percentage error was further reduced (-2.2 to 1.2) and 65 percent of the samples had an error of less than 1 percent. Average percentage error of estimate and percentage mean deviation were of course the same as for the 100-egg samples because both values were averages of identical data.

Although the dry-weight method is technically more accurate,⁸ the estimation of numbers of eggs in lake trout ovaries can be accomplished more easily by the wet-weight method. Eggs need not be removed from the ovary (except in the sample which is counted), the drying process is eliminated, and weighing proceeds more rapidly on a triple-beam than on an analytical balance. In view of the wide variation in numbers of eggs produced by lake trout of similar length or weight, the errors of estimate can be considered unimportant in any practical study of lake trout fecundity.

⁸ In the present study all values for egg production are based either on dry-weight estimates (500-egg samples) or on complete counts.

Still another method of estimating the fecundity of lake trout was employed by Fry (1949) who measured the diameters of 10 maturing eggs and weighed the ovaries; estimates were then made by reference to a conversion diagram showing diameter of maturing eggs plotted against number of eggs per gram of ovary.

Numbers of eggs produced.—In 70 lake trout from southern Lake Superior with total lengths of 25.1 to 38.0 inches and weights of 5.8 to 19.6 pounds, the egg production per fish ranged from 2,476 to 17,119 (Table 8; Figs. 2 and 3). The average number of eggs ranged irregularly upward from 3,383 for fish in the 25.0- to 26.9-inch length class to 13,836 in fish in the 37.0- to 38.9-inch class. However, the individual variability was so great that the maximum number of eggs produced by a

TABLE 8.—*Production of eggs by lake trout in southern Lake Superior*

Total length (inches)		Average weight (pounds)	Number of fish	Number of eggs per fish		Number of eggs per pound of fish	
Interval	Average			Range	Average	Range	Average ¹
25.0-26.9.....	26.0	6.2	9	2,476- 5,645	3,383	400- 844	546
27.0-28.9.....	28.0	7.4	15	3,017- 6,528	4,253	424- 908	573
29.0-30.9.....	30.1	9.4	13	3,622- 7,170	4,995	397- 819	532
31.0-32.9.....	32.2	11.6	17	5,414-12,700	8,667	485-1,093	743
33.0-34.9.....	33.6	13.9	8	5,791-14,260	8,881	441-1,084	645
35.0-36.9.....	35.6	16.5	6	9,062-17,119	11,603	490- 873	705
37.0-38.9.....	37.6	19.3	2	12,906-14,766	13,836	673- 757	715
39.0-40.9.....	40.2	 ²	2	10,877-12,701	11,789	.....	...

¹ Mean of figures determined for individual fish

² These fish were not weighed. Seven unweighed fish of other length classes were not included in this table, but their egg production is plotted in Figure 2

fish in the 25.0- to 26.9-inch group (5,645) was greater than the minimum number produced by a fish of the 31.0- to 32.9-inch class (5,414). The widest range in egg production within any 1-inch or 1-pound interval was between two lake trout, each 33.6 inches long, with weights of 13.1 and 13.2 pounds, and with egg counts of 5,791 and 14,260 (the latter about 2.5 times larger than the former). In each of six 2-inch length classes represented by 6 or more individuals, the maximum egg number was about double that of the minimum count or estimate for a fish of the same length group. This wide range in egg production is not regarded as indicative of, or associated with, racial differences. Fish caught in the same nets at the same time at each of the several localities of collection showed wide variation in egg numbers; nor did commercial fishermen recognize distinct races among the fish used in the fecundity study.

Change in average egg production per pound of fish with increasing size was irregularly upward. A sharp change of level took place between the 29.0- to 30.9-inch and the 31.0- to 31.9-inch intervals when the number of eggs per pound increased from 532 to 743. In the three length classes below 31.0 inches the eggs per pound ranged from 532 to 573; at lengths of 31.0 inches and greater the averages ran from 645 to 743. Grand

average values for the two larger length intervals were: 25.0–30.9 inches, 552 eggs per pound; 31.0–39.9 inches, 711 eggs per pound. Because of this change in egg production with increase in length of the fish, no single figure is accurately descriptive of Lake Superior lake trout. The grand average number of eggs per pound of fish for the lake trout on which the data of Table 8 were based was 646.

In the graphical presentation of data on egg production of lake trout in southern Lake Superior (Figs. 2 and 3) the triangular points represent siscowets, which are discussed separately in the next section. The curves (fitted by inspection) are based only on data for lake trout.

Despite the wide variation in fecundity among individual fish, a line drawn by inspection through the plotted points relating egg production to length (Fig. 2) assumes a sigmoid form. The curve is flattest between

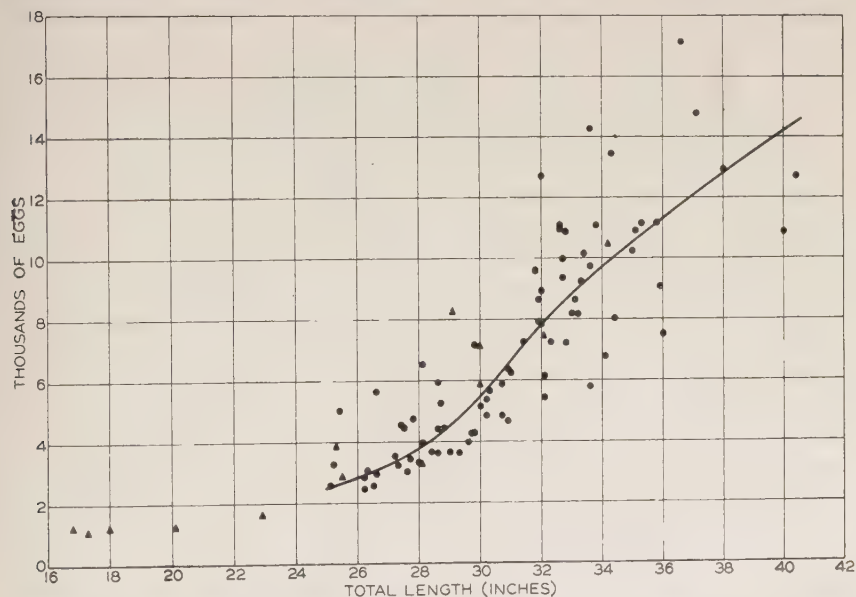


FIGURE 2.—Relationship of length of fish to number of eggs in ovaries of lake trout. Solid dots (on which the curve is based) represent individual lake trout; triangular points are siscowets. The data are summarized in Tables 8 and 9.

the length of 25.0 and 28.0 inches, where it shows an average increase of about 430 eggs per inch increase of length. From this level the curve rises rather abruptly, reaching its greatest slope (about 1,100 eggs per inch of length) between 30 and 33 inches. This steep section reflects the marked increase in egg production of fish of the 31.0- to 32.9-inch length class already noted in Table 8. Beyond 35 inches the slope of the curve decreases gradually; the scattered data for lengths over 36 inches suggest an average increase of about 700 eggs per inch of length.

Although the curve of the relationship of egg production to weight (Fig. 3) gives some indication of a sigmoid form, especially between the weights of 6 and 16 pounds, the straight line seems to give a reasonably adequate fit to the scattered points. This line, drawn by inspection, extends from a production of about 2,900 eggs at a weight of 6 pounds to 14,600 eggs at 20 pounds, and thus has a slope depicting an increase of about 836 eggs per pound increase of fish weight between these extremes.

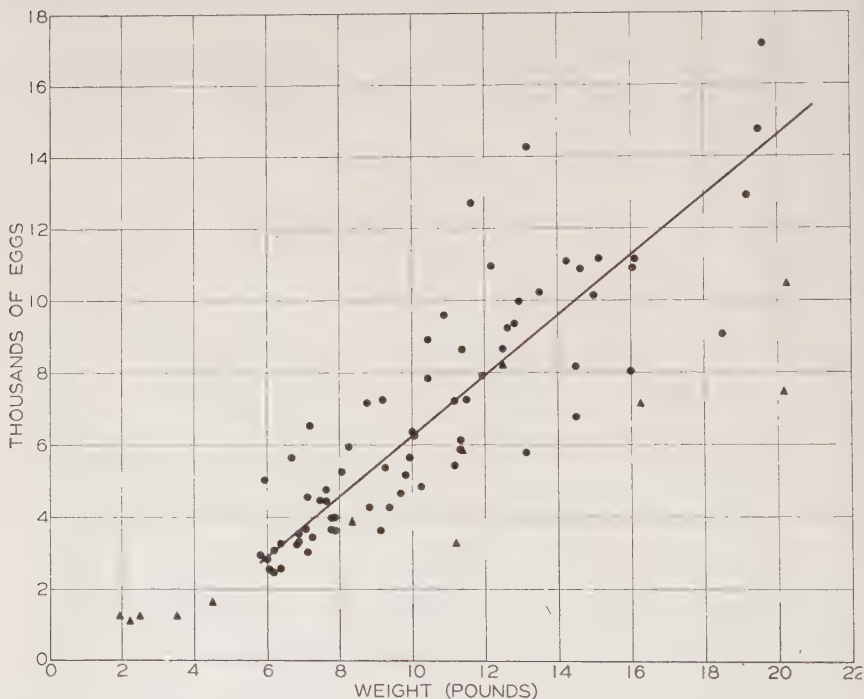


FIGURE 3.—Relationship of weight of fish to number of eggs in ovaries of lake trout. Solid dots (on which the curve is based) represent individual lake trout; triangular points are siscowets. The data are summarized in Tables 8 and 9.

In his study of fecundity of Lake Ontario lake trout, Dymond (1928) found from 2,542 to 18,051 eggs in the ovaries of 25 lake trout (range in fork length, 24 to 35¼ inches) collected August 4–23, 1927, off Port Credit, Ontario. The average production was 721 eggs per pound of fish. Two fish of similar length and weight (26¼ and 27½ inches; 9 pounds, 2 ounces, and 9 pounds, 1 ounce) produced 3,340 and 11,931 eggs, respectively, indicating a wide variation similar to that found in lake trout from Lake Superior. Milner (1874) reported that a 24-pound lake trout from Lake Michigan contained 14,943 eggs. Edward Schneberger (unpublished) determined fecundity of 16 ripe Lake Michigan lake trout in

1936. These fish were from 24¼ to 36 inches long and weighed 4 to 15½ pounds. Egg production ranged from 2,970 to 14,648 eggs per fish, or from 478 to 1,237 per pound of fish (grand average, 776). Fry (1949) reported egg counts for lake trout of Lake Opeongo, Ontario, to range from a mean of 1,200 for age-group V to 15,000 for age-group XVII. Average fork lengths of fish at these ages were 14.6 and 31.4 inches, respectively.

REPRODUCTION OF SISCOWETS

The egg production was determined for 13 siscowets 16.8 to 34.2 inches long, collected at scattered localities in Lake Superior in 1950, 1953, and 1954 (Table 9; triangular points in Figs. 2 and 3). Identity of the specimens is not based on taxonomic characters but on identification by commercial fishermen, who usually separate lake trout ("leans") and siscowets ("fats", and presumed intergrades or smaller fats known as "half-breeds") before marketing the fish. This identification, based largely on quantity of fat lining the body cavity and on gross appearance, seems to be uniform among fishermen of different localities.⁹ Usually the condition factor of fish identified as siscowets is higher (often markedly so) than for lake trout of the same length (*cf.* right-hand column of Table 9 with corresponding data of Table 6). However, this criterion is invalidated by an overlap in coefficient of condition which occurs toward the extremes of the range for each subspecies.

Of the fish for which data are given in Table 9, the 5 smallest were considered half-breeds and the remainder were regarded as fats. They were caught at depths of 50 to 80 fathoms with the single exception of a 22.9-inch fish (No. 5) collected between 10 and 20 fathoms on September 16, 1950. Although siscowets are usually found in deep water (50 fathoms or more), occasional individuals (nearly always half-breeds) occurred in relatively shallow water in the fall of 1950. In addition to the female mentioned, 3 other female and 2 male siscowets were included in a total catch of 81 fish on that date. Of 879 fish caught August 11-November 8, 1950, off Ontonagon, Keweenaw Point, Marquette, and Munising, at depths of 4 to 35 fathoms, 22 (2.5 percent) were siscowets. Of these only 1 male, and the female mentioned above, were sexually mature.

Of great interest in Table 9 are the small mature female siscowets—much shorter than the smallest mature female lake trout collected. These short siscowets were caught about 45 miles north of Grand Marais, Michigan, (Station 16, Fig. 1) on September 28, 1954. The smallest, 16.8 inches long and 1.9 pounds in weight, was 8.3 inches shorter and 3.9 pounds lighter than the shortest and the lightest mature female lake trout in 9 pre-spawning and spawning-run collections in southern Lake Superior in 1950. The catch also included an even smaller, nearly spent female, 16.5 inches long, and a 15.7-inch, 1.3-pound mature (ripe) male.

⁹ Although the siscowet was described as a new species (*Salmo siscowet*) by Agassiz (1850), and is now customarily given sub-specific rank, Jordan and Evermann (1911) and others have expressed doubt as to whether it should be regarded as a distinct species or subspecies.

TABLE 9.—*Egg production of siscowets collected in Lake Superior, 1950-1954*

Specimen number	Date of collection	Locality ¹ of collection	Total length (inches)	Weight (pounds)	Percentage of weight composed by gonads	Number of eggs	Eggs per pound of fish	Diameter of eggs ² (millimeters)	C
1.....	Sept. 28, 1954	16	16.8	1.9	13.9	1,207	635	5.0	40.9
2.....	do.	16	17.3	2.2	11.1	1,093	497	5.0	42.9
3.....	do.	16	18.0	2.5	11.9	1,211	484	5.3	42.9
4.....	do.	16	20.1	3.5	3.5	1,220	346	3.9	43.5
5.....	Sept. 16, 1950	1	22.9	4.5	5.4	1,628	362	4.4	37.5
6.....	Sept. 28, 1954	16	25.3	8.3	3.5	3,861	465	3.6	51.5
7.....	Nov. 22, 1950	11	25.5	 ³	....	2,859	....	4.9	....
8.....	Sept. 28, 1954	16	28.1	11.2	5.2	3,283	293	4.6	50.4
9.....	do.	16	29.1	12.5	3.4	8,243	659	3.4	50.7
10.....	Aug. 18, 1950	6	30.0	11.4	7.0	5,867	515	4.3	42.1
11.....	July 15, 1953	3	30.0	16.2	11.1	7,119	439	5.2	60.2
12.....	Sept. 28, 1954	16	32.1	20.2	10.0	7,435	368	5.3	60.9
13.....	July 25, 1950	9	34.2	20.3	13.0	10,476	516	5.4	50.7

¹ Locality refers to station number, Fig. 1, pp. 49² Average diameter of 25 eggs taken at random from the preserved ovary³ Not weighed

Six fish of each sex were mature in a group of 13 males 15.7–20.9 inches in length and 16 females 16.5–20.8 inches long. Siscowets of this collection, therefore, matured at a much smaller size than did the lake trout of southern Lake Superior.

Despite irregularities, egg production of siscowets tended to increase with increasing length and weight of the fish. Egg numbers ranged from 1,093 in a 17.3-inch fish (No. 2) to 10,476 in a 34.2-inch specimen (No. 13). Production of eggs per pound fluctuated widely and was not correlated with length or weight of the fish. It ranged from 293 eggs per pound in a 28.1-inch fish (No. 8) to 659 in a fish (No. 9) 1.0 inch longer and 1.3 pounds heavier. Average egg production was identical (465 per pound) for 6 fish 25.3 inches or less in length and 6 fish 28.1 inches long or longer. This value is 28 percent less than the grand average egg production (646 eggs per pound) of lake trout of southern Lake Superior (Table 8).

In the graphical presentation of the data on egg production of siscowets (Figs. 2 and 3), no appreciable increase in the number of eggs occurred between lengths of 16.8 and 20.1 inches and weights of 1.9 and 3.5 pounds. From this point the numbers of eggs rose gradually in both graphs. The regression of number of eggs on length (Fig. 2), was similar for lake trout and siscowets. Of 8 siscowets within the range of lengths for which data were available for lake trout, 5 were close (within 600 eggs or less) to the curve drawn for egg production of lake trout. The other 3 were somewhat above the curve, but only 1 was outside the range of variation shown for individual lake trout of about the same length. Seven siscowets between the weights of 8.3 and 20.3 pounds (Nos. 6 and 8–13 of Table 9) showed not only a lower average egg production than did lake trout of comparable weights, but also a lower rate of increase in egg production with increasing weight (Fig. 3).

Milner (1874) found egg production of Lake Superior siscowets to range from 2,796 to 3,756 in 3 fish, and Eddy and Surber (1947) reported an average of 5,000 eggs in 4 females collected off Grand Marais, Minnesota, on July 10, 1938.

In the siscowets (Table 9) as among lake trout (Table 4) the percentage of total weight composed by the ovaries and egg diameter were closely correlated. The egg diameters averaged 5.2 millimeters among the 6 siscowets in which the ovaries made up 10 percent or more of the total weight; 4.4 millimeters for the 3 fish with percentages between 5 and 10; and 3.6 millimeters for the 3 fish with percentages less than 5. The poor correlation between the percentage of the total weight composed by the gonads (or egg diameters) and date of collection in the fish of Table 9 provides strong evidence that the siscowet has an extended spawning season. Two specimens (Nos. 1 and 9), both collected on September 28, 1954, in the same nets, represented the extremes for the series in percentage of the total weight composed by the ovaries (13.9 and 3.4 percent) and a wide divergence in average egg diameters (5.0 and 3.4 millimeters). The first of these fish was nearly ripe whereas the ovaries of the second were green. Two fish, 16.5 and 17.8 inches long which had already

spawned (48 and 14 residual eggs, respectively) were collected on the same date. The ovaries of 2 fish (Nos. 13 and 11) collected on July 25, 1950, and July 15, 1953, were nearly ripe. Although the organs were complete and intact as removed from the fish, eggs were loosely attached and some fell from the preserved ovaries as they were being weighed. The organs had the appearance of nearly ripe lake trout ovaries during the height of the spawning season. Average egg diameters were 5.4 and 5.2 millimeters, respectively. At the other extreme, a siscowet (No. 7) collected November 22, 1950, had not yet spawned, although the diameter of its eggs (4.9 millimeters) indicated that it may have been nearing a ripe condition.

The data of Table 9 permit the assumption that spawning of siscowets may begin by late July and extend at least to late November. An even wider divergence for siscowets (or lake trout) is indicated by the collection on June 8, 1953, of 3 females from 19.4 to 23.4 inches long off Gull Island, near the eastern extremity of Isle Royale (Station 2, Fig. 1). One fish was nearly ripe and 1 was nearly spent. Ripe fish of both sexes were reported by Emil Tormala, the commercial fisherman who made the collections and who fished on this reef during three successive annual spawning runs. The fish were caught at depths of 8 to 15 fathoms, within a few hundred feet of water 75 to 100 fathoms deep. They are known by fishermen as "humpies", and are presumably from a local race, whose affinities with lake trout or siscowets were undetermined.¹⁰ This and the other collections discussed above are the basis for the statement that siscowets or lake trout may spawn in Lake Superior during at least 6 months of the year (June to November).

This wide spread in spawning times corroborates statements of other workers. Milner (1874) noted that spawn in some siscowets was ripe and running freely by the latter part of August and that in September the females were all ripe and depositing spawn. Eddy and Surber (1947) reported the capture of a ripe female and male off Knife River, Minnesota, on November 29, 1923.

The capture of nearly ripe and spent siscowets on September 28, 1954, at depths of 50 to 80 fathoms tends to confirm the statement by Milner (1874) that they have no migratory instinct at this season, but are taken while spawning in the same locality where they were taken previously.

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¹⁰ Analyses of flesh samples from the 3 "humpies" collected on June 8, 1953, and from a series of "leans" and siscowets collected in Lake Superior in 1953 and 1954, were completed by Arthur M. Phillips, Jr., after this paper had been submitted to the printer. Determinations by ether extraction indicated that each of the 3 fish had fat contents well within the range for siscowets, and much greater than that for lean trout of this size. "Humpies" are thus presumed to represent a race of early spawning siscowets.

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BEAVER-TROUT RELATIONSHIP IN THE HEADWATERS OF SUNKHAZE STREAM, MAINE¹

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ABSTRACT

The effect of beaver, *Castor canadensis* (Kuhl), on an eastern brook trout, *Salvelinus fontinalis* (Mitchill), population was studied in the vicinity of five beaver dams in the headwaters of Sunkhaze Stream. The beaver dams were found to present a serious obstacle to trout movements but they were not a complete barrier. Estimated unit-area production of bottom organisms was poor in the beaver ponds but the beaver had so increased the bottom area that total production of the stream section was probably more than doubled. Forage fishes appeared to be somewhat more abundant in the beaver ponds than in the open stream and constituted an unexpectedly high percentage of the food of 6- to 10-inch brook trout taken in the ponds. Measurable but not serious water-quality reduction was found in and below the beaver ponds.

INTRODUCTION

The years since 1931 have seen a remarkable increase in Maine's beaver population. Until the last 20 years beaver were practically unknown except in the remote wilderness. Heavy, unrestricted trapping had virtually exterminated the species. Today, nearly every wooded stream supports at least one colony of beaver. This recovery has been a noteworthy example of the response of an animal population to protection from overcropping.

With the return of the beaver and the establishment of colonies on trout streams, many wondered what the effect on trout fishing would be. Some became convinced that beaver would exert a beneficial influence, and others foresaw the doom of stream trout fishing. Today, a vigorous difference of opinion exists. Any influence of beaver upon trout in streams can be exerted in an indirect manner only; *i.e.*, through the effect of dams and impoundments. Beaver do not feed upon, kill, or molest trout or other fish.

Salyer (1935) and Adams² have investigated beaver-trout relationships in Michigan streams. Rasmussen (1941) studied the effect of introduction of beaver on trout streams in the Rocky Mountain region of Utah. Reid (1952) and Bailey and Stephens (1951) reported on beaver-trout relationships in the mountains of New York and West Virginia, respectively. The general conclusion is that beaver are seldom entirely harmful

¹ Contribution from the Maine Department of Inland Fisheries and Game, Augusta, Maine.

² Adams, Arthur K. 1953. Some physico-chemical effects of beaver dams upon Michigan trout streams in the Watersmeet area. xi + 316 pp. [Typewritten thesis; University of Michigan.]

or entirely beneficial, though Salyer and Reid found beaver to be usually harmful in lowland streams and Rasmussen observed them to be generally beneficial in the cold, precipitous streams of the Utah mountains. The salient beneficial and harmful influences of beaver dams and impoundments cited by these authors may be listed as follows:

Beneficial influences

1. Stabilization of stream flow.
2. Raising temperatures of very cold stream to levels favorable for optimum trout growth.
3. Providing increased bottom area and silt deposition favorable to production of aquatic insects and other trout food organisms.
4. Increasing basic productivity of the stream by favoring growth of plankton organisms.
5. Providing resting, feeding, shelter, and wintering pools for trout in precipitous, shallow streams.

Harmful influences

1. Blocking trout migrations, especially spawning migrations.
2. Raising stream temperatures to levels unfavorable for trout.
3. Changing stream water quality (mainly dissolved oxygen content and pH) to produce
 - a. Unfavorable conditions for trout,
 - b. Unfavorable conditions for trout food organisms.
4. Reducing stream flow during dry periods until little water remains.
5. Providing favorable conditions for predators, competitors, and parasites.
6. Flooding gravel and rubble areas which may be valuable as spawning beds.
7. Deposition of silt in the stream bed below the dam following washout or removal with dynamite. Silt deposition is said often to be great enough to smother food organisms or trout eggs.

Salyer stated that new beaver impoundments usually produce favorable conditions for trout during the first 3 or 4 years of their existence. After that time the flowages "go bad" and trout are affected adversely. Abandoned impoundments are said to create more serious conditions than those inhabited by active colonies.

As beaver increased in Maine, colonies were established on all the tributary and headwater areas of Sunkhaze Stream, Hancock and Penobscot Counties. Sunkhaze is a typical lowland stream that has been known for many years as an excellent producer of eastern brook trout. Anglers state that fishing quality declined markedly during the period of beaver encroachment. This paper presents the results of a study of beaver-trout relationships in the headwater of Sunkhaze Stream.

DESCRIPTION OF THE BEAVER-TROUT STUDY AREA

Study of beaver-trout relationships at Sunkhaze Stream was centered about a series of five active dams in the headwaters. These dams occupied a stream section approximately 1/4 mile long and caused impoundments that merged together to form a flooded area of approximately 3 acres. The largest dam held a 3-foot head of water at normal stream levels; the other dams held 0.5 to 1.5 feet of water. Average depth of standing

water in most of the flooded area was 1.5 to 2.5 feet. Average depth in the stream channel was 3 to 5 feet.

Prior to the establishment of the beaver colonies, the stream banks had been heavily forested with cedar, spruce, and poplar. Flooding killed the terrestrial vegetation and, in 1952, the dead stems of cedars and spruces were still standing in the impounded area. No truly "open water" existed. The sandy bottom of the beaver-impounded area was blanketed with a thick layer of decomposing organic debris. Aquatic vegetation was sparse. The water was dark brown.

Above the impoundments, Sunkhaze Stream is small and moderately steep. The stream bed is mainly fine gravel and sand, grading into rubble and boulders further upstream. Flow at moderate water levels is 1 to 2 cubic feet per second and is supplied largely through surface runoff. Brook trout are not numerous in this small, headwater area.

Below the beaver dams the stream is larger and has a flow of 4 to 6 cubic feet per second. Stream bottom is almost entirely sand with occasional pockets filled with silt and wood debris. Numerous springs add to the flow in this section and in the beaver-impounded area. Small brook trout are numerous in this excellent nursery section.

Beaver maintained the dams in good repair during 1951 and early 1952. In May 1952, the beaver were removed from the area by trapping and, on July 9, the dams were removed with dynamite. No beaver were seen in the impounded area after May and no attempts to restore the dams were made during the remainder of 1952.

Though estimated to be 8 to 10 years old, the beaver ponds provided good fishing in 1951 and 1952. One cooperative party of anglers kept a record of fishing between June 22 and August 5, 1951. These men spent 19 fishing days or 45 fishing hours on the beaver ponds and took 153 brook trout. Catch per trip was 8.0 trout and catch per hour was 3.4 trout. This was the only party that fished the ponds consistently. Heavier fishing would undoubtedly have reduced the exceptionally high catch per unit effort rather quickly. The brook trout taken were small, ranging between 6 and 10 inches, total length. Average size was approximately 6.5 inches. Equally successful fishing was reported in May and June of 1952 but no records were kept.

Fishes common in the beaver-impounded area included:

Eastern brook trout	<i>Salvelinus fontinalis</i> (Mitchill)
White sucker	<i>Catostomus commersoni</i> (Lacépède)
Fallfish	<i>Semotilus corporalis</i> (Mitchill)
Creek chub	<i>Semotilus atromaculatus</i> (Mitchill)
Redbelly dace	<i>Chrosomus eos</i> (Cope)
Ninespine stickleback	<i>Pungitius pungitius</i> (Linnaeus)

MIGRATION

Most authors who have investigated beaver-trout relationships mention the effect of beaver dams as barriers. The average dam 2 to 3 feet high is said to be a serious obstacle to migration, although trout may be able

to pass up or down during periods of high water. Tagging and trapping operations were undertaken to provide quantitative information on the ability of trout to pass the five dams in the headwaters of Sunkhaze Stream.

Two-way, frame-screen traps were operated above and below the beaver dams between June 23 and December 19, 1951, and between April 22 and December 14, 1952. The traps were designed to capture and hold fish moving in either direction. All brook trout taken in the traps were examined, tagged or marked by fin clipping, and released to continue in their original direction of travel. Trout over 5.5 inches, total length, were tagged with serially numbered monel-metal circular jaw tags. Trout under 5.5 inches were marked by fin-clipping. Different series of tag numbers and different combinations of amputated fins were used at each trap each year.

Large numbers of brook trout were taken at the lower trap during 1951 but relatively few were taken at the upper trap. It was expected that removal of the beaver dams in July 1952 would provide a comparison of the relative numbers appearing at each trap before and after dam removal. The "before-and-after" comparison was spoiled, however, by severe drouth conditions during the summer and fall of 1952; the stream above the dams was reduced to pools between July 1 and July 18 and completely dry between July 18 and October 22 of that year. Water levels did not reach normal heights until mid-December and very few brook trout were taken in either trap during the fall of 1952.

During 1951 and in 1952 before the removal of the beaver dams, 904 brook trout were tagged and released at the lower Sunkhaze trap. Of these fish, 440 or 48.7 percent were caught by anglers, found dead, or recaptured in the traps. Some trout were recaptured as many as nine times. The remainder 464 fish, were not seen after tagging. During the same period, 188 trout were tagged and released at the upper trap. Of these fish, 65 or 34.6 percent were recaptured, caught by anglers, or found dead. Analysis of the movement of tagged brook trout past the beaver dams was based on the 505 fish recaptured at least once, caught by angling, or found dead.

As may be seen in Table 1, 6.4 percent of the brook trout tagged below the dams and recaptured at least once were taken after they had ascended the beaver dams and 29.2 percent of trout tagged above the dams were recaptured after they had descended the dams. Recaptures did not noticeably follow freshets that overflowed the dams but the trout may have loitered on the way from the dams to the traps. Size of the trout did not appear to be a factor in dam-passing ability.

No analysis of direction or movement at time of tagging is included in Table 1. This information is omitted because most brook trout remained in the immediate vicinity of the trap at which they were tagged for a part of the experimental period, passing upstream and downstream through the trap at irregular intervals. It was, therefore, impossible to determine whether a fish was "attempting" to pass over the beaver dams or whether

TABLE 1.—*Recovery locations for brook trout tagged above and below the Sunkhaze Stream beaver dams*

Recoveries	Number of brook trout	
	Tagged at lower trap	Tagged at upper trap
Recovered at or near tagging site only	378	31
Recovered at least once at or near opposite trap	13	19
Caught by angling in beaver ponds	15	15
Caught by angling below lower trap	34	....
Total trout recovered at least once	440	65
Trout recovered after passing upstream over dams	28	....
Trout recovered after passing downstream over dams .....	....	19
Percentage of total recoveries	6.4	29.2

his movement was random. The traps were located several hundred yards above and below the uppermost and lowermost dams, respectively. The study would have been improved if the traps could have been located closer to the dams.

It will be noted, further, that the 15 brook trout tagged at the upper trap and caught by angling in the beaver ponds are not included in the total of fish that passed downstream over the dams. Beaver pond angling was concentrated in the pond farthest upstream and trout caught in that pond did not cross a beaver dam in their movement downstream from the upper trap.

The data on fish marked by fin-clipping are of less value than those for tagged brook trout because no identifying mark was added on recapture and one marked fish might have entered a trap several times after ascending or descending the dams. Furthermore, angler returns of marked fish are not reliable because anglers so often overlook amputated fins that numbers reported may bear little relation to numbers caught. However, 1,250 trout were marked at the lower trap and 15 recaptures of these fish were recorded at the upper trap before the dams were removed. Of the 147 trout marked at the upper trap 20 were captured at the lower trap before dam removal. It may be concluded that the beaver dams constituted a serious obstacle to upstream movement of brook trout and a lesser obstacle to downstream movement. The dams were not an impassable barrier.

BOTTOM-FAUNA STUDIES

A study of the bottom fauna of various stream-habitat types at Sunkhaze Stream during 1951 had as its main objective the determination of the effect of beaver impoundment upon food production. Reduction or elimination of bottom fauna is said (Sayler, 1935; Reid, 1952) to be one of the important harmful effects of beaver impoundments on trout streams.

Bottom samples were taken from four limited areas representing distinct stream habitat types on or about the first of each month from May through October 1951. The habitat types of the sample areas were:

1. *Gravel-riffle*. This stream type is characterized by practically continuous shallow riffles, clear water, sparse aquatic vegetation, stream bed composed of loose gravel predominately 1 to 2 inches in diameter, and the water well shaded by overhanging hardwoods. The gravel-riffle sampling area was above the beaver dams. Average stream width in this area is 3 feet; depth is 3 to 6 inches; volume of flow is 1 to 2 cubic feet per second.

2. *Beaver impoundment*. Samples were taken both from the stream channel and from the flooded area of the beaver ponds described above.

3. *Alder-run*. This type is characterized by an even, gentle flow, stream bed mainly fine sand but with numerous silt- and debris-filled pockets, aquatic vegetation moderately abundant in late summer, and the water partly shaded by streamside alders. The sampling area was $\frac{1}{4}$ mile below the lower Sunkhaze trap. Average stream width is 8 feet; average depth is 1 foot; average volume of flow is 6 cubic feet per second.

4. *Rubble-riffle*. This type is characterized by turbulent riffles interspersed with deeper pools, stream bed of rubble 6 to 18 inches in diameter but with some bed-rock and boulders, aquatic vegetation rare, and the water partially shaded by alders and hardwoods. The sampling area was downstream in the main fishing section. Average stream width is 15 feet; average depth is 1.5 feet; average volume of flow is 12 cubic feet per second.

Each bottom sample consisted of the organisms inhabiting 5 square feet of stream bed. Samples were collected in moving-water areas with a Surber square-foot bottom sampler; an Eckman dredge was used for the bottom of the beaver impoundment. Different stations within a sampling area were selected each month to avoid sampling at a previously disturbed spot.

Organisms were fixed and preserved in 70-percent alcohol. Volumes of organisms were determined by displacement in a 15-milliliter graduated centrifuge tube. The average volumes and numbers of bottom organisms per square foot of stream bed taken from each habitat type each month, presented in Table 2, are the averages computed from the 5 square-foot samples.

The rubble-riffle habitat type supported the greatest average summer volume of bottom organisms. The alder-run type supported very large numbers of small organisms. The inference that the former is the better habitat for the growth of large trout whereas the latter is the better nursery area for large numbers of small trout is borne out by field observations.

TABLE 2.—Monthly average volumes (cubic centimeters) and numbers of bottom organisms per square foot of stream bottom

Month	Habitat type							
	Gravel-riffle		Beaver pond		Alder-run		Rubble-riffle	
	Volume	Number	Volume	Number	Volume	Number	Volume	Number
May.....	0.40	M ¹	Tr. ²	1	0.46	29	0.60	25
June.....	0.18	21	0.08	3	0.22	18	0.84	28
July.....	0.14	8	0.06	7	0.22	35	0.52	36
August.....	0.12	31	0.10	12	0.16	25	1.11	38
September.....	0.12	24	0.02	2	0.32	M	1.02	77
October.....	0.18	25	0.06	13	0.70	M	0.80	57

¹ M indicates samples including very large numbers of small insects (mainly *Simulium* spp. and *Chironomus* spp.) not accurately counted

² Tr. indicates a volume less than 0.02 cubic centimeters

The bottom of the beaver impoundment was poorest in both volume and number of organisms per square foot. Since however, beaver dams had increased the original stream-bottom area considerably by ponding the water, comparison of the production of the various habitat types with that of the beaver ponds should be made on an "original area" basis. The beaver impoundments occupied 1/4 mile of stream. The pre-flooding stream channel was approximately 8 feet wide and its bottom area was close to 10,000 square feet. Pre-flooding habitat type was predominately alder-run. Thus, before beaver ponded the water, average summer volume of bottom organisms in the stream section might have been approximately $10,000 \times 0.34 = 3,400$ cubic centimeters.³ The beaver impoundments had an area of approximately 3 acres. Average summer volume of bottom organisms inhabiting the beaver impoundments was estimated at approximately 8,000 cubic centimeters. Impoundment by beaver probably more than doubled the food production of the area.

Further comparisons can be made. If the beaver-impounded area had been rubble-riffle stream type, pre-flooding production might have been somewhat above the actual pond production. If the area had been gravel-riffle type, preflooding production probably would have been about one-quarter of the pond production.

That impoundment by beaver had indeed increased the food production of the impounded area can also be shown indirectly. Anglers found good fishing in the impoundments during 1951 and early 1952. Adjacent stream sections are known as areas in which small fish are abundant and legal fish are rare.

Application of commonly accepted food-grade standards (*cf.* Lagler, 1952) to the Sunkhaze bottom samples would classify the stream as generally "poor" in food production. Only the September sample from the rubble-riffle area classifies Sunkhaze as "average". The good population level and growth rate of brook trout at Sunkhaze Stream suggest that revision of these food grades would be necessary for general use in Maine streams.

The most abundant organisms in the Sunkhaze bottom samples belonged to the nine orders named below. These are listed in the order of their volume abundance in all samples.

Trichoptera	Plecoptera	Rhyncobdella
Ephemeroptera	Megaloptera	Amphipoda
Diptera	Odonata	Coleoptera

In addition to the organisms just listed, small volumes and numbers of fingernail clams, water mites, fresh-water earthworms, and nematodes were taken in the samples. Trichoptera were the most abundant organisms in the rubble-riffle area, Ephemeroptera were most abundant in alder-run area, Odonata were most abundant in beaver pond samples, and Diptera were most abundant in the gravel-riffle area.

³ Summer-long average volume of bottom organisms in alder-run habitat type was 0.34 cubic centimeters per square foot.

FOOD HABITS OF BROOK TROUT

Between May 11 and June 3, 1952, 68 stomachs were collected from brook trout taken by anglers in the beaver ponds. The trout ranged from 6.0 to 10.2 inches, total length. All were caught by bait fishing and all contained food. Forage fishes were the leading food item; they were found in 37 percent of the stomachs and made up 33 percent by volume of all food. Most common fishes were ninespine sticklebacks and redbelly dace. Dragonfly nymphs were also a major food item, occurring in 29 percent of the stomachs and making up 24 percent of the total volume. Terrestrial insects ranked third in importance (in 32 percent of the stomachs; 14 percent of the total volume).

On May 25, 1952, the stomachs of nine brook trout taken by angling 3.5 miles below the beaver dams were collected. These trout ranged between 6.3 and 10.8 inches, total length. All were caught by bait fishing. Eight stomachs contained food, but none contained fish. Mayfly nymphs (Ephemeroptera) and caddisfly larvae (Trichoptera) made up 57 percent of all food. The remainder was unidentifiable insect remains.

The large percentage of forage fishes in the diet of small brook trout in the beaver flowages may indicate that trout in that area take to a fish diet at a smaller size than do trout in other habitat types. The sample is far too small to allow definite conclusions. Stream trout normally change from an insect to a partially piscivorous diet as they increase in size but availability of the various food items plays an important role. General observation indicated that forage fishes were more numerous in the beaver impoundments than elsewhere in the stream.

WATER QUALITY

Salyer (1935), and Reid (1952) have stressed the effects of beaver impoundments on stream's water quality. These authors stated that water-quality changes brought about by beaver dams are often severe enough to make beaver ponds and the stream areas immediately below unsuitable for trout. Salyer remarked that trout from some Michigan beaver ponds are unfit to eat because of the water in which they live.

The causes of such adverse water conditions in beaver impoundments involve complex physical and chemical changes. The more obvious of them are: a marked warming of the water results from the exposure of wide shallow water areas to the sun; the high biochemical oxygen demand of the decaying organic debris abundant in most beaver ponds may rob stream water of its dissolved oxygen.

The planned removal of the Sunkhaze Stream beaver dams in July 1952, provided an opportunity to attempt "before and after" water-quality studies in and around the beaver ponds. The characteristics investigated were temperature, dissolved oxygen, carbon dioxide, and pH.

Dates for water-quality observations were chosen to give determinations during the most critical time of each year. Pre-dam-removal observations were made on August 13, 1951, and post-dam-removal determinations were

made on September 7, 1952. No observations could be made above the site of the beaver dams in 1952 because that section of stream was dry between July 18 and October 22.

The "before and after" data presented in Table 3 are not strictly comparable. Generally lower stream temperatures prevailed at the time of the 1952 samples; consequently the slightly increased oxygen content and pH and the slightly decreased carbon-dioxide content may have the result of lower temperature alone. However, if the 1951 data are considered alone, the table does show higher-than-average stream temperatures and car-

TABLE 3.—*Water quality characteristics at various stations on Sunkhaze Stream before beaver-dam removal in 1951 and after beaver dam removal in 1952*

Station and year	Water temperature (°F.)	Dissolved oxygen (p.p.m.)	Carbon dioxide (p.p.m.)	pH
Gravel-riffle area above beaver dams				
1951.....	65	9.7	3.0	7.0
Beaver flowage (surface)				
1951.....	73	7.0	7.0	6.7
1952.....	54	7.8	5.0	6.9
Fifty yards below beaver dams				
1951.....	70	7.6	8.0	6.6
1952.....	53	8.0	6.2	6.7
One-quarter mile below beaver dams				
1951.....	56	7.9	8.0	6.4
1952.....	50	8.2	6.0	6.7

bon dioxide concentrations and lower-than-average oxygen contents and pH in and below the beaver impoundment during that year. Although the changes produced by impoundment were not great and did not cause unfavorable conditions for brook trout, changes of like magnitude in marginal trout streams might create critical conditions.

Water-temperature observations were made at noon in and below the beaver ponds on July 9, before dam removal and on July 10, the day after dam removal. The degree to which these beaver ponds had been warming the water is shown strikingly in Table 4.

TABLE 4.—*Noon water temperatures (°F.) before and after dam removal*

Location	July 9 (before removal)	July 10 (after removal)
Beaver ponds (surface).....	70	57
Fifty yards below beaver dams.....	66	54
One-quarter mile below beaver dams.....	59	54

The numerous springs in the bottom of the Sunkhaze beaver ponds may have been the only factor which prevented development of adverse conditions. Similar impoundments lacking large springs might show severely unfavorable conditions during critical times of the summer. Extensive water-quality surveys of beaver-impounded streams are needed.

NEED FOR STUDY OF INDIVIDUAL SITUATIONS

The five beaver dams in the headwaters of Sunkhaze Stream were a serious obstacle to upstream migration of brook trout and a lesser obstacle to downstream migration. They were not an impassable barrier. Because suitable feeding, shelter, spawning, and wintering areas are well distributed throughout the trout-inhabited section of Sunkhaze Stream, extensive seasonal migrations are unnecessary and the obstructing effect of beaver dams are accordingly unimportant. Where free migration routes are essential, however, (as in lake tributaries), a delaying obstacle is fully as undesirable as a complete barrier. The removal of beaver and their dams from such waters is entirely justified.

The Sunkhaze beaver ponds were not shown to have adverse effects on the quantity of bottom fauna in alder-run type headwater area. Impoundment in more productive stream-bottom types would probably reduce production to some extent. Examination of stomachs of brook trout collected in the beaver impoundments showed an unexpectedly high percentage of forage fish in the diet of 6.0- to 10.0-inch fish. General observation indicated that forage fishes were somewhat more abundant in the beaver ponds than in the open sections of the stream.

Beaver impoundment in the headwaters of Sunkhaze Stream caused measurable but not serious reduction of water quality. Changes of like magnitude in marginal trout streams might cause critical conditions. Large springs which add to Sunkhaze Stream in the beaver-impounded area may have been the only factor that prevented adverse conditions from developing.

It must be concluded that beaver colonization of trout streams is seldom entirely harmful or entirely beneficial and that the sum effect will be largely determined by stream conditions existing before colonization. In some stream types the harmful effects will outweigh the benefits and beaver control will be necessary. A list of such situations would include: lake tributaries where free migration routes are essential; streams in which the habitat types needed by trout at various times of the year are not widely distributed and seasonal migrations are necessary; marginal trout streams in which slight changes in water quality might produce unfavorable conditions.

In other stream situations the total effect of beaver impoundment will be distinctly beneficial. A list of these would include: streams having poorly protected watersheds where beaver dams would be valuable in stabilizing stream flow; precipitous, mountain streams where beaver create needed shelter and feeding pools and warm the water for maximum trout growth.

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THE EFFECT OF SOME SULFONAMIDES ON THE GROWTH OF BROOK TROUT, BROWN TROUT, AND RAINBOW TROUT

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ABSTRACT

Sulfonamides such as sulfisoxazole (Gantrisin[®]), sulfamerazine, and a mixture of sulfamerazine with sulfaguanidine were fed to apparently normal fingerlings of brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and rainbow trout (*Salmo gairdneri*). None of these drugs had any growth-affecting influence on rainbow trout. Growth of brook trout was somewhat retarded by sulfamerazine. The retardation of the growth of brown trout was greater with sulfamerazine than with the mixture of two sulfonamides. Sulfisoxazole did not retard growth of any of the three species. As soon as the medicated food was replaced with normal, brown trout resumed growth. Observations are also furnished on the tissue levels of sulfonamides and hemoglobin in the experimental trout.

INTRODUCTION

A desirable chemotherapeutic agent should stop development or, even better, should kill the pathogens in tissues of the infected animal or plant and should be relatively harmless to the host. Unfortunately such "ideal" drugs do not exist, and the margin of safety varies with different agents, depending on the species treated.

Since sulfonamides are used widely in the treatment of bacterial fish diseases, one should bear in mind the observation that "... there are no drugs of which more side-effects are mentioned in the literature than the sulfonamides" (Meyler, 1952). Highly specific reactions to sulfamerazine have been shown in brook trout, brown trout, and rainbow trout (Gutsell and Snieszko, 1949). Johnson and Brice (1953) observed a toxic effect of sulfamerazine to fingerling coho salmon (*Oncorhynchus kisutch*). Earp, Ellis, and Ordal (1953) reported that treatments with sulfadiazine or sulfamethazine were apparently harmless to spring chinook salmon (*O. tshawytscha*) and sockeye salmon (*O. nerka*). Therefore the effects of

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sulfonamides, or other drugs, on fishes should be determined before they are used for the therapy of various bacterial diseases.

The studies reported here were carried out to determine the effect of certain sulfonamides on the growth rate of three species of trout. Sulfisoxazole was tested because of its lack of toxicity to poultry (Tabenkin, *et al.*, 1953), and for its effectiveness in the treatment of kidney disease in brook trout (Snieszko and Griffin, 1955). A mixture of sulfamerazine with sulfaguanidine was superior to sulfamerazine alone in the treatment of furunculosis in brown trout (Flakas, 1950). Sulfamerazine was included to permit a close comparison of the results with those of Gutsell and Snieszko (1949). Any substantial difference between the present results and those obtained by Gutsell and Snieszko would support the belief that the response was lot- rather than species-specific. In case of such lot-specificity, further research of this type would have little significance, whereas proof of a constant species-specificity of the effects of various sulfonamides on fishes would be of considerable practical importance.

MATERIALS AND METHODS

Fingerling brook, brown, and rainbow trout were distributed in 500-gram quantities among experimental troughs. The following treatments were selected: 1. sulfamerazine, 2. sulfamerazine 6 parts and sulfaguanidine 4 parts; 3. sulfisoxazole (Gantrisin[®])⁴; 4. controls (no medication). All drugs were administered with food at a rate of 200 milligrams per kilogram of fish per day. The drugs were mixed first with the dry portion of the diet and then added to the meat. The full diet consisted of 25 percent dry mixture and 75 percent meat. The dry mixture was made of equal parts by weight of cottonseed meal, fish meal, distiller's solubles, wheat middlings, and 4 percent table salt. Meat consisted of equal parts of beef liver and beef spleen. Food was given twice daily; the rate was 8 percent of the weight of trout per day. There was only one feeding on Sundays, thus the fish received half of the daily ration on that day. All tests were made in duplicate. Water temperature was 12.2° C. (54° F.).

The experiment was started on April 12 and finished on July 12, 1954. Fish were weighed at 2-week intervals. Following each weighing, fish in excess of 500 grams were removed. After 8 weeks, the experiment was terminated with brook trout and rainbow trout, but was continued with brown trout, the species most affected by the treatments. During the ninth week hemoglobin and the tissue levels of sulfonamides were determined in 5 trout selected at random from each trough.

At the end of the ninth week the brown trout fingerlings in each pair of troughs receiving the same treatment were pooled and distributed in 220-gram quantities into four experimental troughs. Trout in two of these troughs remained on the medicated diet and the other half received the same food without sulfonamides. The purpose of this test was to determine whether fingerling brown trout stunted on the diet containing sulfamera-

⁴ Furnished free of charge by Hoffmann-La Roche, Inc., Nutley, N. J.

zine, and sulfamerazine with sulfaguanidine, would resume normal growth on a food free from these drugs. The experiment with these brown trout was continued for an additional 4 weeks (total, 13 weeks).

Trout selected at random from each trough were used for histological examination and determination of the tissue concentration of sulfonamides and hemoglobin. To minimize the danger of contamination by regurgitated food when fish were killed, trout did not receive any food during the 24 hours prior to examination. The intestinal tract was removed. Fish were ground in a Waring blender with distilled water and the sulfonamides determined in an electric colorimeter by the method of Bratton and Marshall (1939) as described by Levinson and MacFate (1946).

EFFECTS ON GROWTH

The effect of sulfamerazine on the growth of all three species of trout (Table 1; Fig. 1) was of the same nature as reported by Gutsell and Snieszko (1949). The growth rate of rainbow trout was not affected, but in brook trout growth was reduced about 30 percent during the 8 weeks. The greatest effect occurred in brown trout which showed growth about 450 percent greater in the controls than in the fish receiving sulfamerazine. These results indicate that the reaction to sulfamerazine in brook, brown, and rainbow trout fingerlings is species-specific and apparently of the same magnitude in different lots of fish tested at intervals of several years. It is strongly probable that the effects of sulfisoxazole and the mixture of sulfamerazine with sulfaguanidine are also species-specific and that the results

TABLE 1.—Response, expressed as percentage gain in weight, of normal fingerling brook, brown, and rainbow trout to a diet containing several sulfonamides administered at a rate of 200 milligrams per kilogram of fish per day

Sulfonamide and species of trout	Average percentage gain per two troughs by 2-week periods				Total percentage gain per trough April 12–June 7		Total mortalities per treatment
	1	2	3	4	A	B	
Sulfisoxazole							
Brook trout.....	55	36	42	39	178	166	5
Brown trout.....	40	33	30	28	132	130	4
Rainbow trout.....	38	38	34	27	138	136	2
Sulfamerazine							
Brook trout.....	41	26	25	21	112	114	5
Brown trout.....	16	5	8	0	24	34	17
Rainbow trout.....	30	26	36	38	128	132	4
Sulfamerazine with Sulfaguanidine							
Brook trout.....	39	30	31	28	140	116	6
Brown trout.....	28	8	10	3	44	54	17
Rainbow trout.....	31	28	27	29	118	112	0
Controls							
Brook trout.....	48	43	36	32	164	154	5
Brown trout.....	44	37	34	25	138	142	8
Rainbow trout.....	34	34	34	31	136	130	4

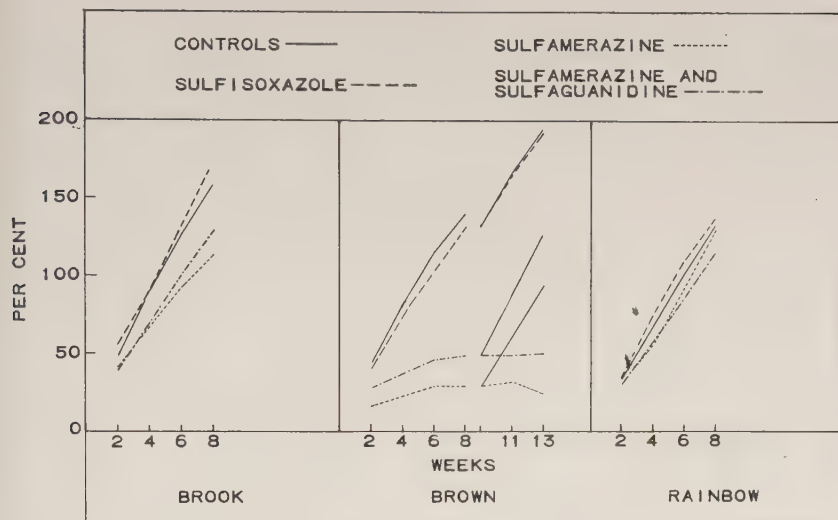


FIGURE 1.—Growth of three species of fingerling trout fed diet containing 200 milligrams of sulfonamides per kilogram of fish per day as compared with growth of controls receiving the same diet but without sulfonamides.

can reasonably be applied to other treatments of the same species of trout with the same drugs.

The growth rate of brook and brown trout treated with a mixture of sulfamerazine and sulfaguanidine was somewhat better than that of the fish receiving sulfamerazine. The difference may explain why an outbreak of furunculosis in brown trout responded more favorably to treatment with the above-mentioned mixture than with sulfamerazine alone (Flakas, 1950).

Sulfisoxazole had only a slight growth-retarding effect on brown trout and appeared even to stimulate the growth of brook and rainbow trout.

The strong growth-retarding effect of sulfamerazine alone or with sulfaguanidine on brown trout was apparently due to a gradual loss of appetite in the treated fish. From the second week brown trout nearly stopped taking food containing these sulfonamides. So much food was left over in the troughs that it is surprising that any growth took place and that sulfonamides were present in the tissue extract. When the medicated food was replaced after 9 weeks with normal diet, the growth rate of brown trout returned to normal (Fig. 1; Table 2). This observation as well as the lack of any pathological changes in the treated brown trout seems to indicate that in this species sulfamerazine alone or with sulfaguanidine causes some physiological upset which gradually reduces the appetite. If refusal to take food were abrupt and displayed also by brook trout and rainbow trout, one could suspect that aversion to the medicated diet was caused by its taste. Slight loss of appetite was also noticed in

TABLE 2.—*Growth and mortality of fingerling brown trout maintained for 13 weeks on a diet containing sulfonamides, and growth of fish fed the medicated diet for 9 weeks followed by a normal diet for 4 weeks*

[All fish received medication, April 12–June 14. Troughs were standardized at 220 grams each on the latter date. Beginning June 14, medication was terminated for two lots but was continued for two others. Duplicate lots are indicated as A and B]

Item	Average number of trout per trough June 14	Percentage gain or loss per trough June 14–July 12		Number of mortalities per trough June 14–July 12	
		A	B	A	B
Sulfisoxazole					
With drug, April 12–July 12.....	32	+60	+63	..	..
Without drug, June 14–July 12.....	31	+61	+67	..	..
Sulfamerazine					
With drug, April 12–July 12.....	72	– 5	– 6	7	9
Without drug, June 14–July 12.....	61	+65	+66	2	..
Sulfamerazine with Sulfaguanidine					
With drug, April 12–July 12.....	64	– 6	+ 9	6	2
Without drug, June 14–July 12.....	63	+69	+84	..	..

brook and rainbow trout receiving sulfamerazine alone and in a mixture with sulfaguanidine. No reduction of appetite, as compared with the controls, was noticed in any trout given sulfisoxazole.

The barely perceptible growth-stimulating effect of sulfisoxazole on brook or rainbow trout is so small that it has no practical importance. It may have occurred due to control of some low-grade infection.

In the determination of sulfonamide levels in the tissues of experimental trout, the lowest readings were found in trout treated with Gantrisin (Table 3). This observation is in agreement with our preliminary test which indicated that tissue levels of sulfisoxazole in brook trout decrease rapidly. This is also true in humans where "the higher rate and rapidity of elimination of the drug explain the low levels attainable in the blood and body fluids" (Sophian, Piper and Schneller, 1952, p. 57).

Hemoglobin levels of control fish were perceptibly lower in brown trout than in brook or rainbow trout. The hemoglobin contents increased by about 10 percent in brook trout receiving sulfamerazine and in brown trout

TABLE 3.—*Concentration of sulfonamides (milligrams per 100 grams of fish) in the tissues of experimental trout*

[Each reading represents a composite sample of 10 trout. The last feeding of medicated food was given 24 hours before the determinations were made on June 9, 1954]

Species	Sulfisoxazole	Sulfamerazine	Sulfamerazine and sulfaguanidine ¹
Brook trout.....	...	3.8	3.0
Brown trout.....	0.8	2.1	1.2
Rainbow trout.....	0.9	6.6	4.1

¹ The drugs were in the ratio of 6 parts of sulfamerazine to 4 parts of sulfaguanidine. The concentration was calculated on the basis of the tissue levels as previously determined for both sulfonamides separately (Snieszko and Friddle, 1951)

treated with the mixture of sulfamerazine and sulfaguanidine. No significance would be attached to this observation if it were not in general agreement with observations reported earlier by Gutsell and Snieszko (1949) and Gutsell (1951).

Histological examination revealed no tissue damage in the kidneys or other organs regardless of the species of trout or type of sulfonamide. More detailed histopathological observations will be reported elsewhere (Wood, Yasutake, and Snieszko, 1955).

The possibilities of sulfisoxazole in the therapy of fish diseases have so far been tested only (and with good results) in the treatment of kidney disease in brook trout (Snieszko and Griffin, 1955). The observation that this drug has no growth-depressing effect on any species of trout is especially promising for the therapy of bacterial diseases of brown trout, since growth of this species is greatly depressed by sulfamerazine alone or in a mixture with sulfaguanidine. In the lower warm-blooded vertebrates as in the chickens (Tabenkin, *et al.*, 1953) no evidence of toxicity was observed after feeding a diet containing a high concentration of sulfisoxazole. In fact, as in fishes, (Table 1, Fig. 1) this drug was observed to stimulate growth if added to the chicken diet in concentrations of 0.03 to 1.0 percent.

Until it becomes known how effective sulfisoxazole will be in the treatment of trout suffering from other bacterial diseases than the kidney disease, it should be used on the experimental basis only. Caution is recommended since it is well known that chemotherapeutic agents are species-specific in regard to their side effects on the hosts and the control of pathogenic bacteria. Therefore results obtained in the treatment of one disease in one species of fish can not be generalized without experimental support.

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FISH MORTALITY CAUSED BY ELECTRICAL SHOCKERS ¹

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ABSTRACT

Under experimental conditions legal-sized brook trout, brown trout, and rainbow trout exposed to 110-volt alternating- and 230-volt direct-current electricity suffered an average mortality of 6.4 percent. Immediate mortality amounted to 4.3 percent and the delayed type accounted for 2.1 percent of the deaths. Of the trout exposed to alternating current 11.1 percent died whereas only 2.0 percent of those treated with direct current were killed. There appeared to be no relationship between mortality and either fish size or trout species. Both types of units are considered to be acceptable for stream population studies.

INTRODUCTION

The electrical fish shocker, either alternating current or direct current, has become a widely accepted tool in the field of fish management, and particularly in studies of stream-fish populations. Although fish mortality due to shocking has been given some consideration by such workers as Hauck (1949), Holmes (1949), Shetter (1947), and Smith and Elson (1950), most of the experimentation to date has been aimed at increasing the fish-catching efficiency of the equipment under a variety of field conditions, and little attention has been paid to fish mortality or to means of minimizing it.

Fish mortality need not be considered when the shocking device is used merely to collect fish. On the other hand, mortality from shocking will cause a systematic error in population studies by the mark-and-recovery method, leading to estimates which are too great. Such mortality seems to be of two types. Some of the shocked fish die without recovering consciousness. A second type of mortality may occur from a few to several days after the fish appear to have recovered from the electrical shock and subsequent handling. If the latter type is common and the extent of such losses is unknown, the value of the electrical shocker in estimating the size of fish populations will be greatly impaired.

The previous studies on mortality caused by shocking have shown a wide variation in death rate. Hauck (1949) reported a 26-percent kill in the rescue of large rainbow trout (average weight, 3.7 pounds) from an Idaho irrigation canal. His equipment consisted of a 495-watt, 110-volt A.C. generator, and hand-held electrodes. Shetter (1947), using similar

¹ Contribution of the University of Idaho, the Institute for Fisheries Research of the Michigan Department of Conservation, and the University of Michigan cooperating.

equipment on smaller trout in Michigan streams, found that the mortality rate was generally less than 1 percent. Other workers have noted this apparent relationship between mortality rate and size of fish. It has also been observed that certain species are more readily affected by electricity than are others (Smith and Elson, 1950; Larkin, 1950).

EQUIPMENT AND METHODS

Since work by the writer on Michigan streams involved the use of the electrical shocker in estimating fish populations, it was necessary to measure the mortality caused by the equipment then in use. During the summer of 1950 the extent of fish mortality caused by both alternating and direct current was measured at the Almena sub-station of the Wolf Lake Hatchery, Michigan Department of Conservation. The shockers used in these experiments consisted of 110-volt A.C. and 230-volt D.C. portable power plants and hand-held grid-type electrodes. This equipment has been described in detail in a previous publication (Pratt, 1952).

The physical and chemical conditions of the water appeared to be well within the limits deemed necessary for good results with the shocker. The resistivity of the water was approximately 3,250 ohms per cubic centimeter at 25°C., the pH was 8.0, and the methyl-orange alkalinity was 140 p.p.m., expressed as calcium carbonate, on May 31 and June 19.

Four-hundred fifty legal-sized (7 inches or more, total length) brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and rainbow trout (*Salmo gairdneri*) were used in the experiment. The brook trout averaged 9.9 inches in total length, the brown trout 7.7 inches, and the rainbow trout 7.5 inches. Fifty individuals of each species were marked by removing the anal fin and were shocked with alternating current. An additional 50 individuals of each species, marked by the removal of the adipose fin, were shocked with direct current. A third group of 50 of each species were observed as controls after having been marked by removal of the dorsal fin. The control group was handled in the same manner as the others except that they were not exposed to electrical shock. Shocking of the two experimental groups was accomplished by creating an electrical field in one of the raceways, and holding the fish, a few at a time, in scap nets in the electrical field. The fish which were exposed to alternating current were held 1 foot from the electrode for 15 seconds. Those shocked with direct current were also held in the field 15 seconds, 1 foot from the positive electrode.

The two groups were shocked on May 31, June 19, and again on July 6 when the experiment was terminated. Between exposures, all groups were randomly mixed and placed in two raceways, over which wires were strung at approximately 1-foot intervals to prevent predation by fish-eating birds. The fish were seined from the raceways in order to separate the three groups prior to shocking. Hatchery personnel visited the raceways daily to feed the fish and to collect any dead specimens.

FISH MORTALITY

Both immediate and delayed mortality were observed during the experiment (Table 1). All of the fish which were killed immediately had been left in the electrical field longer than the prescribed period. These fish escaped from the scap nets and were lost from view in the water made turbid by the seining operations. As a result, they lay on the bottom directly under the electrodes for several minutes before they were found.

During the experiment cooperating hatchery personnel found 6 fish which had died, but an additional 24 trout were not recovered at the termination of the tests. It is assumed that these fish were actually removed from the raceways and did not die and remain unobserved, since the hatchery personnel made observations daily. The fish were probably removed by poachers who were driven from the property on the night of June 12 but there is also possibility of animal predation. In either case the missing trout were no doubt taken from the raceways and are therefore, excluded from the sample on the assumption that their loss was due to causes other than the experimental treatment.

TABLE 1.—Comparison of immediate and delayed mortalities in three species of trout exposed to electrical shock and handling

Group	Immediate mortality			Delayed mortality ¹			Total number recovered		
	May 31, 1950			May 31, 1950 to June 19, 1950			June 19, 1950		
	Brook	Brown	Rainbow	Brook	Brown	Rainbow	Brook	Brown	Rainbow
Control.....	..	..	..	..	.. (4)	..	50	46	50
A. C. current...	1	2	2	1 (3)	2 (10)	.. (2)	45	36	46
D. C. current...	..	..	..	..	2 (1)	1 (2)	50	47	47
Group	June 19, 1950			June 19, 1950 to July 6, 1950			July 6, 1950		
	Brook	Brown	Rainbow	Brook	Brown	Rainbow	Brook	Brown	Rainbow
	Brook	Brown	Rainbow	Brook	Brown	Rainbow	Brook	Brown	Rainbow
Control.....	..	..	2 ¹	.. (1)	.. (1)	..	49	45	49
A. C. current...	3	4	..	..	..	..	42	32	45
D. C. current...	..	..	..	..	..	..	50	47	47
Totals.....	4	6	3	1	4	1	141	124	141

¹ Parentheses indicate fish not recovered and assumed to have been removed by poachers

² Caught in the seine and accidentally crushed by foot of operator

Of the corrected number of 282 fish shocked and accounted for, 6.4 percent (18 fish) died. Total immediate mortality amounted to 4.3 percent (12 fish), and delayed mortality accounted for 2.1 percent (6 fish). Of the 135 trout exposed to alternating current, 11.1 percent (15 fish) died, whereas only 2.0 percent (3 fish) of the 147 treated with direct current were found dead. This difference is highly significant by the chi-square test (Chi-square, 61.7). Electrical shock is apparently responsible for the

deaths rather than handling, since there were no dead fish among the control individuals.

The relationship of fish size to mortality by electrical shock reported by some workers (Hauck, 1949; Rayner, 1949) was not evident in these tests. Although the total lengths of the fish ranged from 6.5 to 13.6 inches there were as many deaths among the small individuals as among the large ones. Neither was there conclusive evidence that one trout species is more susceptible than others to death by electrical shock. Such differential mortality among less closely related species has been reported (Larkin, 1950).

Under the experimental conditions alternating current caused higher fish mortality (11.1 percent) than did direct current (2.0 percent), yet with neither did the kill approach that recorded by some workers (*e.g.*, Hauck, 1949). The mortality rate in the present experiment was no doubt higher than that in stream population studies, because streams usually have no great concentrations of fish near the electrodes, and the operators move the electrodes rapidly so that paralyzed fish, even if unseen, do not remain very long in the electrical field. Such was not true in the raceways.

From the above experiment and from observations during actual population studies, it appears that in streams of comparable physico-chemical characteristics fish mortality caused by electrical fish shockers of the types described will be negligible. These units should continue to prove valuable in estimating stream-fish populations.

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TOXICITY OF BRINE WATER FROM OIL WELLS

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ABSTRACT

Studies of the median toxicity thresholds for 10 species of fish in brine wastes from a single oil well showed a range of the thresholds from 4.3 to 11.2 percent of the original brine by volume. A similar study on 10 kinds of invertebrates revealed a range of thresholds from 1.8 to 8.7 percent. Thresholds were expressed as percentage volume of the original waste since the brine contained large amounts of calcium, magnesium, potassium, and sodium as well as chloride ions. However, computations of hypothetical combinations of chlorides in the brine indicated sodium chloride to be present in such proportions as to be most toxic.

Median toxicity thresholds were determined also for six species of fish and five kinds of invertebrates in tap water and sodium chloride. A comparison of these thresholds with those in brine wastes, expressed as p.p.m. hypothetical sodium chloride, revealed that three species of fish (plains killifish, gambusia, and the black bullhead) could withstand more sodium chloride in brine wastes than in a solution of sodium chloride alone, whereas the reverse was true for the other three species (green sunfish, red shiner, and the fathead minnow). The thresholds were similar, however; those of brine fell within the fiducial limits of the thresholds in sodium chloride. Four of five kinds of invertebrates withstood slightly less sodium chloride (hypothetical) in brine than in a solution of sodium chloride alone. A somewhat better agreement between the thresholds in brine and in sodium chloride was obtained if the thresholds were expressed as p.p.m. chloride and p.p.m. sodium ions. In the two solutions, the threshold concentrations were much closer for sodium than for chlorides for the plains killifish, gambusia, and bullheads. For the green sunfish, red shiner, and fathead minnow, however, the threshold values in brine and in sodium chloride were much closer expressed as p.p.m. chloride than as p.p.m. sodium.

A comparison of the chloride-ion tolerance of three species of fish and three kinds of invertebrates in laboratory experiments and from field observations indicated similar tolerance for all forms in the two situations.

Preliminary studies on the acclimation of plains killifish to sodium chloride indicated that this species could withstand 8,649 p.p.m. more sodium chloride when it had been living in waters containing 6,329 p.p.m. chloride than when it had been in waters containing less than 100 p.p.m. chloride. Differences of temperatures did not affect the median toxicity threshold appreciably, but the mortality rate increased with the temperature.

Future studies on these wastes should include work on the antagonistic effects of calcium, magnesium, sodium, and potassium in the presence of the chloride ion.

The presence of calcium, magnesium, sodium, and potassium ions in brine wastes in high concentrations along with chloride ions creates important questions.

INTRODUCTION

Brine from oil wells is a major source of pollution in the southwestern United States. The quantity of sodium chloride that fish can tolerate is believed to be near the osmotic pressure of their own blood—about 6

atmosphere or approximately the equivalent of 7,000 p.p.m. sodium chloride (Duval, 1925; Ellis, 1937). However, information of tolerance levels for individual species of freshwater fish in sodium chloride is fragmentary (see Ellis, 1937, for a review). Data on tolerance levels of freshwater invertebrates are equally scarce; this subject has been treated recently by Anderson (1950). A review of the effects of sodium chloride on domestic and on industrial water supplies, in irrigation, in stock and wildlife watering, and on fish and other aquatic life has been issued by the California State Water Pollution Control Board (1952). Few records have been located that deal with the tolerance levels of fish and invertebrates to brines from oil wells. Brine wastes contain a mixture of calcium, sodium, magnesium, and potassium chlorides and undoubtedly some soluble oil products are present. This paper reports a study of the tolerance levels of certain freshwater fish and invertebrates to brine wastes.

METHODS

Brine wastes, as they flowed from a pipe line into a stream, were taken and diluted with tap water. A series of 10 dilutions was made according to a method described by Anderson (1944), with the exception that 1,000 milliliters were used instead of 100. An electric stirrer insured uniform mixing when water was added. The experiments were conducted in a manner described by Doudoroff *et al.* (1951) and calculations were made by means of formulas and tables given by Weil (1952). Those formulas took into account the dilution sequence which progressed logarithmically by 0.125 in all experiments. Most test organisms were collected in the vicinity of the laboratory, but the sports fish were provided from the state hatchery at Durant, Oklahoma. All experiments were run for at least 96 hours, and the median toxicity threshold (MTT) is expressed for this time. Fiducial limits on the 95-percent level are given for each threshold.

The amount of chloride ions in the wastes was determined by the Volhard method. Readers are cautioned to pay particular attention to the methods of expressing the median toxicity thresholds, which vary throughout the paper but are always indicated. Results have been corrected for the high specific gravity. All experiments were concluded at the temperatures indicated, plus or minus 1° C.

The following species of fish were used in the toxicity studies: plains killifish (*Fundulus kansae*), gambusia (*Gambusia affinis*), white crappie (*Pomoxis annularis*), bluegill (*Lepomis macrochirus*), green sunfish (*Lepomis cyanellus*), channel catfish (*Ictalurus punctatus*), red shiner (*Notropis lutrensis*), black bullhead (*Ameiurus melas*), largemouth bass (*Micropterus salmoides*), and fathead minnow (*Pimephales promelas*). Invertebrates employed as test animals included four crustaceans—water fleas (*Daphnia pulex*), copepods (*Diaptomus clavipes*), sideswimmers (*Hyalella azteca*), and crayfish (*Cambarus* sp.)—as well as one snail (*Physa*), one annelid (Tubificidae), and four kinds of aquatic insects, namely: a dragonfly (Libellulidae) and a damselfly (Coenagrionidae), the

burrowing mayfly (*Hexagenia*), and a free-ranging species of mayfly (*Baetidae*) found on wave-swept shores.

CHEMICAL COMPOSITION OF BRINE AND DILUENTS

The brine wastes used in this study had high concentrations of chlorides, 119,000 p.p.m., but other anions occurred in quantities not uncommon in natural water. Concentrations of several cations were high: sodium, 59,700 p.p.m.; calcium, 11,100 p.p.m.; magnesium, 2,070 p.p.m.; potassium, 1,140 p.p.m.; and iron, 7.0 p.p.m. The wastes were hard (36,200 p.p.m. CaCO_3) and acid pH 6.0). Concentrations of all the above ions in these wastes were considerably higher than is common in fresh-water streams of Oklahoma and about twice as high as in sea water (Table 1). The ions

TABLE 1.—Comparisons of the chemical composition of sea water, salt brine from oil wells, University of Oklahoma tap water, and Crystal Lake water, Norman, Oklahoma
[Unless stated otherwise, all values are p.p.m.]

Item	Sea water ¹	Salt brine ²	Tap water, University of Oklahoma ²	Crystal Lake water ³
Silica (SiO_2).....	.....	.....	12	6.8
Iron (Fe).....	0.002-0.02	7.0	0.02	42.8
Calcium (Ca).....	400	11,100	4.0	21.4
Magnesium (Mg).....	1,272	2,070	2.8	6.9
Sodium (Na).....	10,561	59,700	127.0	20.2
Potassium (K).....	380	1,140	1.1	.....
Carbonate (CO_3).....	.....	.....	16	.....
Bicarbonate (HCO_3).....	.....	51	310	121.1
Sulfate (SO_4).....	.....	297	15	13.2
Chloride (Cl).....	18,980	119,000	4.8	10.0
Fluoride (F).....	.....	.....	0.1	.....
Nitrate (NO_3).....	.....	.....	1.4	.....
Dissolved solids.....	.....	206,000	336	142
Hardness (as CaCO_3)				
Total.....	.....	36,200	22	.....
Non-carbonate.....	.....	36,200	.....	.....
Specific conductance at 25° C. (microhmos)	.....	175,000	554	.....
pH.....	.....	6.0	8.7	.....
Color (units).....	.....	5.0	5.0	.....
Percentage sodium ⁵.....	.....	78	92	.....
Specific gravity.....	.....	1.15	.....	.....

¹ Sverdrup, Johnson, and Fleming (1942)

² Analysis made by U. S. Geological Survey, Stillwater, Oklahoma

³ Leake (1945)

⁴ Iron and aluminum

⁵ Percentage of cations

in the brine were not in the same proportions as sea water. The above mentioned chemical analyses were assumed to represent the wastes that were collected monthly from the same well, since only the chloride concentration was determined monthly.

Hypothetical combinations in the brine yield 152, 168 p.p.m. of sodium chloride, 30,351 p.p.m. calcium chloride, 8,106 p.p.m. of magnesium chloride, and 2,174 p.p.m. potassium chloride. Sulphates and carbonates

were relatively low—420 p.p.m. calcium sulphate and 42 p.p.m. calcium carbonate.

The diluent was non-chlorinated tap water, relatively soft and with high alkalinity (Table 1).

MEDIAN TOXICITY THRESHOLDS OF CERTAIN FISH IN A BRINE WASTE

The median toxicity thresholds were determined for 10 species of fish in brine wastes diluted with tap water (Table 2). Thresholds ranged from 11.2 percent by volume of wastes for the plain killifish to 4.2 percent for the fathead minnow. *Gambusia*, green sunfish, red shiners, black bullheads and largemouth bass had the respective thresholds: 7.4, 5.5, 5.1, 5.0, and 4.6 percent. White crappie, bluegill, and channel catfish had respective thresholds of 6.1, 5.5, and 5.4 percent, but these values were considered only preliminary since fewer than 10 fish per concentration were used.

TABLE 2.—*The median toxicity thresholds (MTT) for fish in a brine waste at a 96-hour exposure*

[Number of concentrations was 10 for each species]

Fish	MTT (percentage volume) ¹	Confidence interval (0.95)	Temperature (°C.)	Number of fish per concentration	Average length of fish (inches)
Plains killifish.....	11.2	12.4—10.2	16	10	1.7
<i>Gambusia</i>	7.4	8.5—6.4	25	10	1
White crappie.....	6.1	7.0—5.3	23	3	2
Bluegill.....	5.5	6.4—5.0	23	6	2
Green sunfish.....	5.5	5.8—4.8	23	10	2
Channel catfish.....	5.4	6.1—4.8	23	5	2.7
Black bullhead.....	5.0	5.9—4.4	23	10	3
Red shiner.....	5.1	5.9—4.4	23	10	1.2
Largemouth bass.....	4.6	5.9—4.9	23	10	3.5
Fathead minnow.....	4.3	4.9—3.8	23	10	1.7

¹ Percentage by volume of brine waste in the total volume of the test mixture.

VARIATION IN THE MEDIAN TOXICITY THRESHOLDS

An appreciation of the innumerable factors that may influence the median toxicity threshold may be gained from Doudoroff *et al.* (1951). Some idea of the effects of using acclimated and unacclimated test animals as well as the effects of temperature and type of diluents have been established by our own preliminary experiments.

Variation of chemical composition of brine.—Since brine wastes were collected monthly from an outlet of a given oil well, the median toxicity threshold for a given species of fish could vary according to the variation of the chemical composition of the brine wastes. Parkey¹ reported quantitative changes in the chemical composition of brine wastes. For instance, the chloride concentration of the wastes from one well changed from

¹ Parkey, Fred. 1952. A study of salt water contamination to the underground water in the Big Wichita River Valley. A mimeographed report to the Board of Directors of Wichita County Water Improvement Districts No. 1 and 2, Texas.

24,400 to 2,600 p.p.m. chloride in a single month. In eight other wells he studied, however, the chloride concentration remained nearly constant during the two consecutive months of study.

Because complete chemical analyses of the wastes were impractical each month, chloride determinations were made in order to check the main ingredient. Bioassay experiments with the red shiner revealed the monthly variation of the killing effect of the brine wastes. The chloride concentrations and the toxicity thresholds for the red shiner in brine wastes remained about the same from December 1952 to May 1953 (Table 3). On the basis

TABLE 3.—*Monthly chloride concentrations of brine wastes from the same well and the respective median toxicity thresholds (MTT) for the red shiner*

Date of Collection	Chlorides (p.p.m.)	MTT (percentage volume)
December 11, 1952.....	116,000	5.1
January 20, 1953.....	116,000	5.2
January 31, 1953.....	103,000	5.6
March 10, 1953.....	113,000	5.1
May 4, 1953.....	118,000	5.1

of these results, the assumption was made that the killing power of the wastes probably showed slight variation when other species of fish were used.

The effect of acclimation.—Plains killifish were collected from two tributary streams on the same watershed. In one stream, the chlorides were never found to be greater than 100 p.p.m. In the other, which constantly received brine wastes, chlorides ranged during the previous year from 8,346 p.p.m. to 19,520 p.p.m.; the chlorides at the time of collection were only 6,329 p.p.m. Killifish were found in these polluted waters throughout the year and apparently completed their life cycle in waters of high chloride concentration since a 10-foot waterfall prevented migration upstream to this point. They were the only species of fish found in these high-chloride waters.

Median toxicity thresholds were determined for both the acclimated (from high-chloride waters) and the unacclimated (from unpolluted waters) killifish in brine wastes and in sodium chloride. The thresholds for the acclimated fish were higher in both experiments. In brine wastes, the median toxicity threshold for the acclimated fish was 16.7 percent (range 15.8-16.9) and for the unacclimated fish 11.2 percent (range 10.2-12.4). In sodium chloride solution the median toxicity threshold for acclimated fish was 24,649 p.p.m. NaCl (range 22,390-27,133) and for the unacclimated fish 16,000 p.p.m. (range 13,847-18,491). The killifish probably is capable of a high degree of acclimation since a number of species in this genus inhabit brackish and salt water.

An experiment in which 184 red shiners were held in brine for over a period of 4 months indicated that this fish made little if any adjustment to gradually increasing concentration of brine wastes.

The effect of different diluents.—Median toxicity thresholds were the same for gambusia when sodium chloride was diluted first with Norman tap water and then with Crystal Lake water. (For comparison of the chemical content of the two diluents see Table 1.) If other diluents were used, differences in the median toxicity thresholds might be revealed, although the authors feel such differences may be of little practical significance.

The effect of temperature.—The median toxicity thresholds for the red shiner in brine were the same at 8°, 23°, and 26° C. The rate of kill increased, however, with the temperature. Similarly, thresholds for the red shiner and the fathead minnow in sodium chloride were about the same at 23° C. as they were at 28° C. (Table 4).

TABLE 4.—*Relationship of temperature to median toxicity threshold (96-hour exposures)*
[The diluent was tap water in all experiments]

Fish and MTT	Temperature (°C.)	Toxicant	Fish and MTT	Temperature (°C.)	Toxicant
Redshiner			Fathead minnow		
5.1 percent	8	Brine	8,954 p.p.m.	23	Sodium chloride
5.1 percent	23	do.	8,361 p.p.m.	28	do.
5.1 percent	26	do.	Gambusia		
9,760 p.p.m.	23	Sodium chloride	10,670 p.p.m.	23	do.
10,350 p.p.m.	28	do.	14,600 p.p.m.	28	do.

TABLE 5.—*The median toxicity thresholds (MTT) for invertebrates in a brine waste at 96-hour exposure*

[Number of concentrations was 10 for each group]

Organism	MTT (percentage volume)	Confidence interval (0.95)	Temperature (°C.)	Number of specimens per concentration
<i>Cambarus</i>	8.7	9.7—8.0	16	10
<i>Libellulidae</i>	7.2	7.9—6.2	23	10
<i>Coenagrionidae</i>	7.2	8.4—6.2	23	6
<i>Hexagenia</i>	5.1	5.5—4.5	23	10
<i>Tubificidae</i>	4.9	5.4—4.4	23	6
<i>Hyalella</i>	3.8	3.9—3.7	23	10
<i>Baetidae</i>	3.6	3.9—3.4	23	10
<i>Diaptomus</i>	3.2	3.6—2.9	16	10
<i>Physa</i>	3.1	3.3—2.8	23	10
<i>Daphnia</i>	1.8	2.1—1.6	16	10

Thresholds for gambusia in sodium chloride, however, were 10,670 p.p.m. NaCl at 23° C. and 14,600 p.p.m. NaCl at 28° C.

Median toxicity thresholds of certain invertebrates in a brine waste.—The median toxicity thresholds were determined for 10 kinds of invertebrates in brine diluted with tap water (Table 5). *Daphnia pulex* was the most susceptible, having a threshold of 1.8 percent. *Diaptomus clavipes*, *Physa*, *Baetidae*, and *Hyalella azteca* were next with the respective thresholds of 3.1, 3.2, 3.6, and 3.8 percent. Tubifex worms, mayflies (*Hexagenia*), damselflies (*Coenagrionidae*), and dragonflies (*Libellulidae*) followed with respective thresholds of 4.9, 5.1, 7.2, and 7.2 percent. Cray-

fish (*Cambarus*), the most tolerant of the invertebrates, had a threshold of 8.7 percent.

EVALUATION OF MEDIAN TOXICITY THRESHOLD IN BRINE

When the hypothetical chemical combinations in brine wastes were reviewed (Table 1) the question arose as to the combination most hazardous to aquatic life. Some appreciation of the nature of the problem may be gained from the comparison of thresholds for *Daphnia magna* in separate solutions of calcium, magnesium, sodium, and potassium chlorides with the concentration of these chlorides in the brine (Table 6). It is seen that the concentration of sodium chloride in the brine is 41.3 times that of the threshold for *Daphnia magna* whereas the next strongest chloride was calcium chloride which was only 32.9 times that of the threshold for *Daphnia magna*. Thus sodium chloride in brine wastes appeared to be the limiting factor, for when the wastes were diluted to concentrations below

TABLE 6.—Comparison of various toxicity thresholds to the hypothetical concentration of each chloride in the brine wastes

[Factors were obtained by dividing the threshold concentration for each chloride into the hypothetical concentration of that chloride in the brine.]

Animal	NaCl	CaCl ₂	MgCl ₂	KCl	Authority
<i>Daphnia magna</i>	41.3	32.9	10.9	5.0	Anderson, 1950
<i>Gammarus fasciatus</i>	59.9	6.9	....	27.8	Clemens, 1950
<i>Notropis blennioides</i>	60.8	10.9	17.0	5.8	Garrey, 1916
<i>Carassius auratus</i>	12.9	3.9	1.2	29.1	Powers, 1917
<i>Notemigonus crysoleucas</i>	30.5	4.9	6.8	....	Weibe, Burr, and Faubion, 1934

the threshold for water fleas in sodium chloride, the concentration of the other chlorides were also below threshold level. This point can be demonstrated again for young *Gammarus fasciatus* with the data of Clemens (1950). From similar considerations with the data of Garrey (1916) on the straw-colored minnow, Powers (1917) on goldfish, and Wiebe, Burr, and Faubion (1934) on the golden shiner, sodium chloride seems to be the limiting factor where data are available, except for magnesium chloride, which, according to Powers' data, would have a more toxic effect than sodium chloride.

Calcium chloride may be the limiting factor for some animals, however. Anderson (1950) pointed out that certain aquatic animals tolerate more sodium ions than calcium ions and others tolerate more calcium ions than sodium ions.

Many physiologists may disapprove of comparisons of the type just given in view of the complex antagonistic effects of calcium, magnesium, potassium, and sodium as described by Heilbrunn (1952). We accordingly conducted the experiments described in the next section to determine the threshold for certain fish and invertebrates in solutions of chemically pure sodium chloride in tap water for comparison with the threshold in brine wastes.

MEDIAN TOXICITY THRESHOLDS OF CERTAIN FISH IN SODIUM CHLORIDE

The median thresholds in a solution of sodium chloride and tap water were determined for six species of fish (Table 7). Thresholds ranged from 16,000 p.p.m. NaCl for the plains killifish to 7,994 p.p.m. for the black bullhead. Other median toxicity thresholds were: green sunfish, 10,713 p.p.m.; gambusia, 10,670 p.p.m.; red shiner, 9,513 p.p.m.; fathead minnow, 8,718 p.p.m. The experimental fish were about 1 inch long with the exception of green sunfish and bullheads, which averaged 2 and 3 inches, respectively.

TABLE 7.—The median toxicity thresholds (MTT) for fish in sodium chloride at 96-hour exposures

[Number of concentrations was 10 for each species]

Fish	MTT (p.p.m. NaCl)	Confidence interval (0.95)	Number of fish per concentration	Temperature (°C.)
Plains killifish.....	16,000	18,491—13,847	10	15
Green sunfish.....	10,713	12,368—9,232	10	23
Gambusia.....	10,670	12,327—9,231	10	23
Red shiner.....	9,513	10,898—8,496	10	23
Fathead minnow.....	8,718	9,875—7,700	10	23
Black bullhead.....	7,994	9,232—7,000	10	23

MEDIAN TOXICITY THRESHOLDS OF CERTAIN INVERTEBRATES IN SODIUM CHLORIDE

Determinations of the median toxicity thresholds in tap-water solutions of chemically pure sodium chloride were made also for five kinds of invertebrates (Table 8). Crayfish and dragonflies were the most tolerant, having thresholds of 17,403 and 15,943 p.p.m. NaCl, respectively. The common pouch snail, *Physa*, the copepod, *Diaptomus clavipes*, and the water flea, *Daphnia pulex*, possessed much lower thresholds—5,353, 4,329, and 2,932 p.p.m. NaCl, respectively.

COMPARISON OF THRESHOLDS OF FISH IN BRINE AND IN SODIUM CHLORIDE

Comparison of the median toxicity thresholds of fish in brine, expressed as p.p.m. of the hypothetical combination of sodium chloride in the wastes, with those of fish in chemically pure sodium chloride and tap water (Table 9) revealed that the thresholds for the plains killifish, gambusia, and black bullhead were higher in brine than in sodium chloride. For these fish the ions may have been acting antagonistically. Garrey (1916) showed that mixtures of salts become progressively less toxic when calcium chloride, then potassium chloride, and finally magnesium chloride have been added to a sodium chloride solution (in California State Water Pollution Control Board, 1952). The determination of the threshold for gambusia in the brine wastes was made at a temperature 2° C. higher than that of the threshold in sodium chloride; consequently the two may not be fully

TABLE 8.—*The median toxicity thresholds (MTT) for invertebrates in sodium chloride at 96-hour exposures*

[Number of concentrations was 10 for each group]

Organism	MTT (p.p.m. NaCl)	Confidence interval (0.95)	Number of specimens per concentration	Temperature (°C.)
<i>Cambarus</i>	17,403	19,000—15,933	10	16
<i>Libellulidae</i>	15,943	17,520—14,521	10	16
<i>Physa</i>	5,353	5,879—4,873	10	23
<i>Diaptomus</i>	4,239	4,709—3,817	10	16
<i>Daphnia</i>	2,932	3,319—2,672	10	16

TABLE 9.—*Comparison of the various expressions of thresholds (MTT) for fish in brine with the respective threshold in sodium chloride*

[96-hour exposures]

Fish	Brine wastes			Sodium chloride (p.p.m. NaCl)
	MTT (percentage)	MTT (p.p.m. Cl)	MTT (p.p.m. hypo- thetical NaCl)	
Plains killifish.....	11.2	12,717	18,783	16,000
Gambusia.....	7.4	8,592	12,690	10,670
White crappie.....	6.1	7,068	10,439	.....
Bluegill.....	5.5	6,330	9,349	.....
Green sunfish.....	5.5	6,330	9,349	10,713
Channel catfish.....	5.4	6,308	9,317	.....
Red shiner.....	5.1	5,960	8,803	9,513
Black bullhead.....	5.0	5,802	8,569	7,994
Largemouth bass.....	4.6	5,380	7,346	.....
Fathead minnow.....	4.3	4,883	7,212	8,718

comparable. The thresholds for the green sunfish, red shiner, and fathead minnow were lower in the brine wastes than in the sodium chloride. For these species the ions may have been acting synergistically or perhaps the greater toxicity of the brine might have resulted from the presence of toxic soluble oil products. For all species, however, the thresholds had similar values; those for the brine fell within the fiducial limits of the thresholds in sodium chloride.

A somewhat better correspondence was obtained when thresholds in brine and in sodium chloride were expressed for each solution as p.p.m. chloride and also p.p.m. sodium (Table 10). The thresholds in the brine and in the prepared solutions were much closer for sodium than for chlorides for the plains killifish, gambusia, and bullheads. In the green sunfish, red shiner, and fathead minnow, however, the thresholds in brine and sodium chloride agreed better when they were expressed as p.p.m. chloride than when they were stated as p.p.m. sodium. These observations suggest that some ions are more toxic to certain fish than to others. This problem needs further investigation which would include analyses of brine wastes and a more discriminating comparison of thresholds with respect to the ion concentration.

TABLE 10.—*A comparison of the thresholds (MTT) of certain fish in brine wastes and in sodium chloride when the thresholds were expressed as p.p.m. chloride and p.p.m. sodium*
[96-hour exposure]

Fish	MTT in brine (p.p.m. Cl)	MTT in sodium chloride (p.p.m. Cl)	MTT in brine (p.p.m. Na)	MTT in sodium chloride (p.p.m. Na)
Plains killifish.....	12,717	9,705	6,066	6,295
Gambusia.....	8,592	6,472	4,098	4,198
Black bullhead.....	5,802	4,849	2,767	3,145
Green sunfish.....	6,330	6,498	3,019	4,215
Red Shiner.....	5,960	5,770	2,843	3,743
Fathead minnow.....	4,883	5,288	2,329	3,430

COMPARISON OF THRESHOLDS OF INVERTEBRATES IN BRINE AND IN SODIUM CHLORIDE

The thresholds for four of the five kinds of invertebrates in brine, expressed as p.p.m. hypothetical sodium chloride, were lower than thresholds of invertebrates in a solution of sodium chloride and tap water (Table 11). The differences were small, however; the thresholds in brine fell within the confidence intervals of those in sodium chloride.

COMPARISON OF THRESHOLDS IN THE LABORATORY WITH FIELD DATA

The median toxicity thresholds of certain fish and invertebrates were compared to the highest chloride concentration in which organisms were found during a year's study on Salt Creek, a brine-polluted tributary of the Little Washita (Table 12). Chlorine concentrations in this part of the study were stated as p.p.m. chloride since expressions involving the hypothetical combinations of chlorides require complete inorganic chemical analysis—a procedure not practical when numerous determinations were needed. Some idea of the chemical composition of brine water in the stream at a heavily polluted station may be had from the following analysis:

TABLE 11.—*Comparison of the thresholds (MTT) for invertebrates in brine with the respective threshold in sodium chloride*
[96-hour exposure]

Organism	Brine wastes		Sodium chloride
	MTT (percentage volume)	MTT (p.p.m. hypothetical NaCl)	MTT (p.p.m. NaCl)
<i>Cambarus</i>	8.7	12,834	17,403
<i>Libellulidae</i>	7.2	10,620	15,943
<i>Diaptomus</i>	3.2	4,780	4,239
<i>Physa</i>	3.1	4,530	5,353
<i>Daphnia</i>	1.8	2,705	2,932

TABLE 12.—Comparison of brine tolerance of fish and invertebrates in laboratory and in field experiments

Organism	Laboratory data MTT (p.p.m. chloride)	Field data Highest concentration in which animal was collected (p.p.m. chloride)	
		Clemens and Jones	Lewis ¹
Plains killifish.....	212,717	19,520	29,975
Red shiner.....	6,345	8,319	4,295
Fathead minnow.....	5,193	7,859	4,295
Crayfish.....	10,440	5,940	.....
<i>Daphnia</i>	2,513	1,749	.....
Dragonfly.....	8,639	9,487	.....
Black bullhead.....	5,802	.....	2,201
Largemouth bass.....	5,380	.....	1,384
Channel catfish.....	6,308	.....	1,384
Green sunfish.....	6,330	.....	3,816

¹ Lewis, Leo D. 1952. A story of the effects of salt water on fresh-water fish in the Big Wichita River System. Mimeographed report to board of directors of Wichita County Water Improvement Districts No. 1 and 2, Texas, pp. 1-8.

² Fish used were not acclimated to brine wastes: acclimated fish had a threshold of 18,898 p.p.m.

N. C. hardness as CaCO_3 .. 4,380 p.p.m.	Potassium (K) {	5,700 p.p.m.
Total hardness as CaCO_3 .. 4,590 p.p.m.	Sodium (Na) {	
Dissolved solids 20,600 p.p.m.	pH	7.2
Specific conductance at 25° C. (micromhos) ...29,900	Bicarbonate (HCO_3)	260 p.p.m.
Specific gravity 1.013	Sulfate (SO_4)	131 p.p.m.
Calcium (Ca) 1,390 p.p.m.	Chloride (Cl)	11,800 p.p.m.
Magnesium (Mg) 274 p.p.m.	Nitrate (NO_3)	4.3 p.p.m.

However, the brine used in the laboratory experiments was from a different oil field than that which polluted the stream (compare above analysis with the analysis of brine in Table 1).

In the field, the plains killifish, red shiner, and fathead minnow were found in higher chloride concentrations than they tolerated in laboratory experiments. The data are difficult to evaluate, however, because it is not known whether fish were resident in or were migrating through this stream section. The plains killifish probably were living in the stream and data indicated that they had withstood chloride concentrations of around 19,000 p.p.m. ($\pm 1,000$ p.p.m.) for about a month. Lewis collected the plains killifish in waters containing 29,975 p.p.m. chloride (Table 12). Acclimation doubtless contributed to the high tolerance to chloride in the stream. This view is supported by the fact that killifish that had been living in water with a chloride concentration of 6,329 p.p.m. had a median toxicity threshold of 24,649 p.p.m. NaCl —8,649 p.p.m. higher than the threshold for fish taken from water containing less than 100 p.p.m. chloride.

The red shiner taken in water with a chloride concentration of 8,319 p.p.m. may have been in the stream section only a short time, but a single fish was collected again, a month later when the chloride concentration was 7,859 p.p.m. No red shiners were obtained in the next three collections

when chloride concentrations rose to about 9,000 p.p.m. It is possible that a few red shiners may tolerate chloride concentrations in the neighborhood of 8,000 p.p.m. Red shiners did occur regularly at a downstream station immediately before the confluence of Salt Creek and the Little Washita, where chloride concentrations ranged up to 5,734 p.p.m. They were not taken at this station, however, during 2 weeks in October when chloride concentrations were 6,525 and 6,699 p.p.m. These seemingly prohibitive concentrations of chloride approximate the 6,345 p.p.m. obtained in the laboratory. Lewis found the red shiner in waters containing as high as 4,295 p.p.m. chloride in the Big Wichita River, Texas (Table 12).

Evaluation of field observations on the fathead minnow was difficult owing to the fish's irregular occurrence along Salt Creek. Eleven fish were captured in September, 3 miles upstream from the confluence of Salt Creek and the Little Washita when the chloride concentration was 7,859 p.p.m. and four fish were collected again in November when chloride concentration was 5,940 p.p.m. The six other occurrences in Salt Creek during the year were in places where the chloride concentration was 3,646 p.p.m. or below. Lewis found the fathead minnow in the Big Wichita River in chloride concentrations as high as 4,395 p.p.m.

The median toxicity thresholds obtained in the laboratory for the black bullhead, largemouth bass, channel catfish and the green sunfish were considerably higher than the highest chloride concentration in which Lewis, Table 15, found these fish in the Big Wichita River, Texas. This is difficult to evaluate for other factors in the habitat may have kept the fish from entering the higher chloride waters. At the same time, it is expected that the chloride tolerance of fish will be somewhat lower in the stream than the values determined from 100-hour experiments in the laboratory.

Comparisons of laboratory and field data in the instances of invertebrates did not involve the same species and therefore were only valid on the generic level for the crustaceans and the family level for the dragonflies. In all cases, laboratory data approximated the field data. The median toxicity threshold for crayfish was 10,440 p.p.m. while irregular collections showed that crayfish were collected in chloride concentrations of 5,940 p.p.m. although chlorides the previous month were 9,912 p.p.m. at this station and it seemed probable that crayfish were there at this time but were not collected. The median toxicity threshold for dragonflies was 8,639 p.p.m. while a different species was found living in Salt Creek at 9,487 p.p.m. chloride. *Daphnia* occurred rarely in the watershed of the Little Washita and was collected once in Salt Creek at a concentration of 1,749 p.p.m. The median toxicity threshold for *Daphnia* was 2,513 p.p.m. chloride.

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MINNOW PRODUCTIVITY IN A SMALL ILLINOIS STREAM

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ABSTRACT

As a means of evaluating the effects of harvesting minnows in a small stream, a study was made of the minnow population in a section of Jordan Creek in east-central Illinois. Nine collections of minnows were made with an electric fish shocker from August 1950 through October 1953. These collections represented a large proportion of the existing population. The yields for the corresponding months of each of the succeeding years increased progressively. The minnow population as a whole exhibited annual cycles of abundance and of average weights of individual fish. Each species responded differently to various environmental factors and to the continuous cropping. Shocking, which is a more effective method of harvesting minnows than is seining, did not reduce the minnow population in the study section of Jordan Creek longer than a few months. The natural fluctuations of the minnow population made it difficult to measure the effects of cropping with the electric shocker.

INTRODUCTION

Many restrictions are now imposed on the taking of minnows from our lakes and streams, even to the extent that some states prohibit the taking of minnows at any time from any natural water. Other states close only certain counties or drainage systems, or have only a short closed season on minnows. These restrictions have different objectives in different states but in general they were adopted to serve one or more of the following purposes: to preserve a natural supply of bait for fishermen; to prevent destruction of food supplies of game fish; to prevent the losses of young game fish which might be destroyed during seining operations; to reduce competition with the commercial dealer who rears his own minnows.

MINNOW HARVEST IN JORDAN CREEK

The effects of harvesting minnows in a stream were studied as one phase of a major investigation of the fish population of Jordan Creek, a small warm-water stream in east-central Illinois. The minnow population in a section of this stream was cropped at regular intervals with an electric fish shocker. This section of Jordan Creek is characterized by short, rocky riffles and relatively deep pools. It is 0.9 mile long, averages about 22 feet wide, and has an area of 2.4 acres of water at average summer water level.

The same collecting procedure was used each time. A 30-foot electric seine powered from a 115-volt A.C. generator was employed by three men.

All minnows seen were collected in dip nets with $\frac{1}{4}$ -inch mesh and taken to the laboratory for sorting according to species and size, counting, and weighing. This collecting procedure, as well as the habitat and fish population of Jordan Creek, has been described by Larimore, Pickering, and Durham (1952).

Nine collections were taken from the area. The first was taken in August 1950, two collections were made in 1951, and three each year in 1952 and 1953. A total of 76,217 minnows were removed. These minnows weighed 522.0 pounds or 217.5 pounds per acre of water (Table 1). For the corresponding months of each of the succeeding years, the yields increased progressively (Fig. 1). The August collections showed an increase from 15.0 pounds per acre in 1950 to 52.1 pounds per acre in 1953. The total yield for 1953 was 40,645 minnows, weighing 243.5 pounds, or 101.5 pounds per acre. This yield of fish appears to be rather heavy especially in view of the following points:

1. This water produced a complementary crop of suckers and darters.
2. The average water depth is approximately 1 foot so that this yield per acre could also be considered yield per acre-foot.

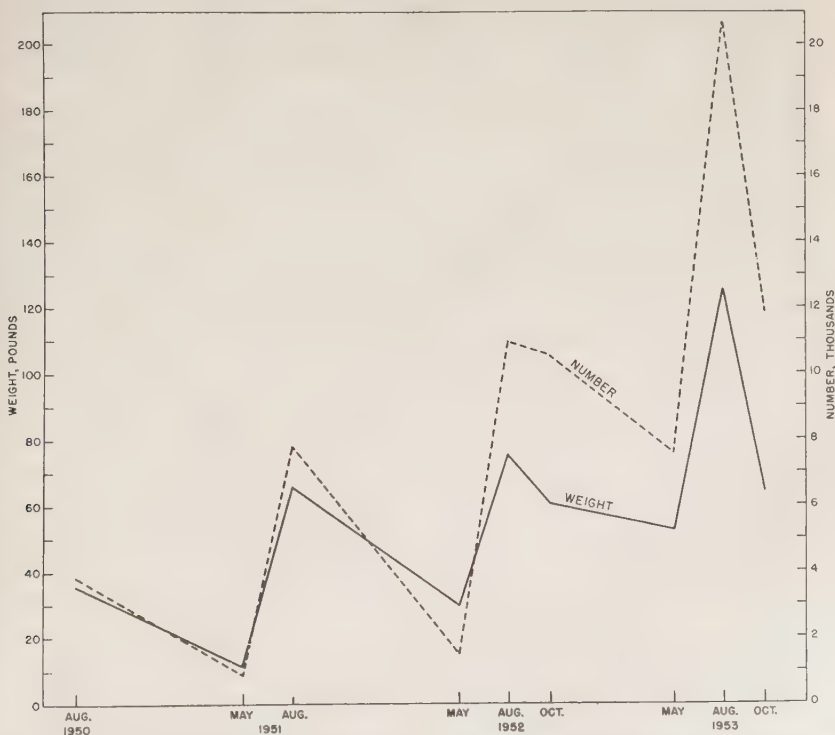


FIGURE 1.—Total numbers and weights of minnows removed from a 0.9-mile section of Jordan Creek.

3. Our electric shocker killed about 50 percent of the minnows present at the time of shocking. The percentage killed varied with water temperatures, species, and size of fish. Operating at a collecting efficiency of roughly 50 percent (which seems low only to those biologists who have not checked the efficiency of their operations or who have not collected in this kind of stream), we left as dead minnows in the creek approximately 25 percent of the existing minnow population. This percentage can be considered the unharvested yield, which, if added to the 1953 crop, would give a total production of 152 pounds of minnows per acre actually removed from the population.

POPULATION CHANGES

Interpretation of the population changes involves distinguishing the effects of cropping from the fluctuations that would naturally occur. The changes that have taken place in the minnow population in this cropped area have been compared with changes in the relative abundance of the same species found at the same time in other parts of Jordan Creek. These changes relate to the major study mentioned earlier and are too complex to be discussed at length here. However, certain points can be brought out concerning the population changes exhibited in Table 1 and Figures 1 and 2.

First, the minnows followed a definite annual cycle of abundance, the numbers were low in the spring, increased during the summer as the young of new broods were added to the population, and then declined during the winter (Fig. 1).

Second, the average weight of the minnows, all species considered together, also followed an annual trend (Table 1). The average weight was greatest in the spring when small fish were scarce and large breeding

TABLE 1.—*Minnows collected from a 0.9-mile section of Jordan Creek, August, 1950 to October, 1953*

Date of collection	Total numbers	Total weight (pounds)	Average weight (pounds)	Weight per acre
1950				
August.....	3,820	35.9	0.0094	15.0
1951				
May.....	890	11.2	0.0126	4.7
August.....	7,825	65.9	0.0084	27.5
1952				
May.....	1,473	29.5	0.0200	12.3
August.....	10,978	75.8	0.0069	31.6
October.....	10,586	60.2	0.0057	25.1
1953				
May.....	7,572	52.2	0.0069	21.8
August.....	20,679	125.1	0.0060	52.1
October.....	12,394	66.2	0.0053	27.6
Total.....	76,217	522.0	.....	217.5

individuals were numerous. Even though all members of the population may have been growing rapidly, the average size declined during the summer because of the addition of great numbers of small fish. These cycles were strongly influenced by weather conditions that affect the reproduction, survival, growth, and movements of the minnows.

Third, each species of minnow responded differently to various environ-

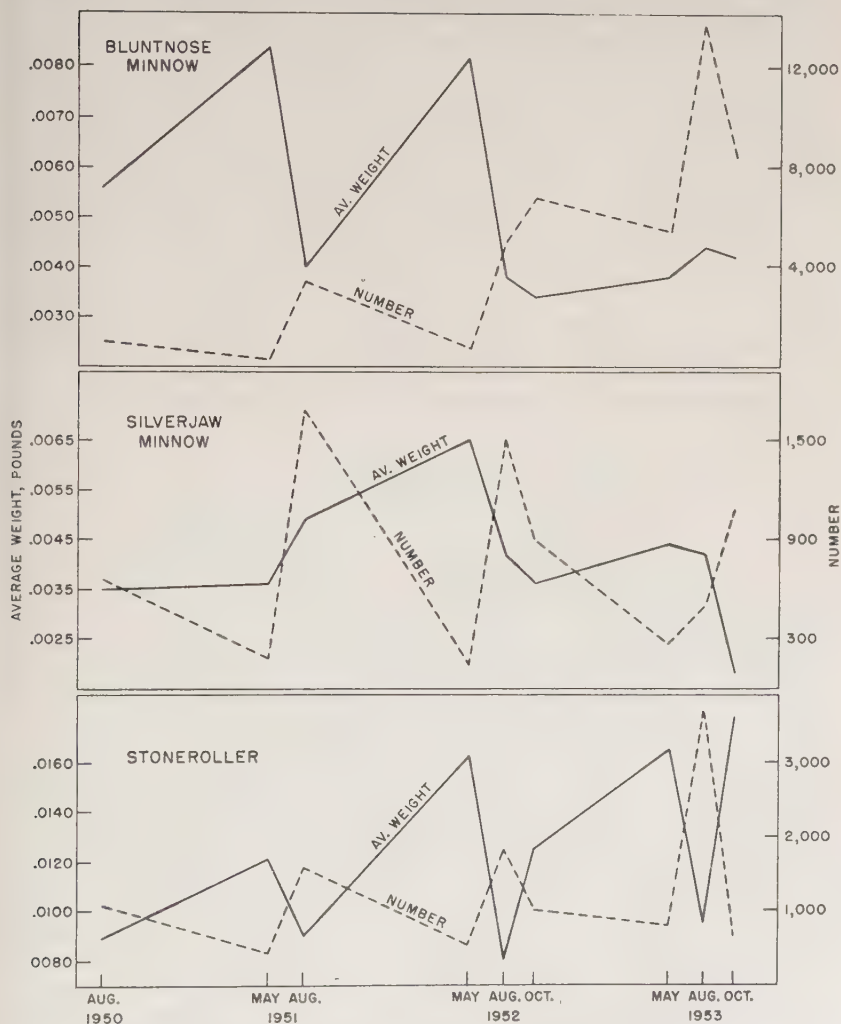


FIGURE 2.—Numbers and average weights of individuals of three species of minnows removed from a 0.9-mile section of Jordan Creek.

mental factors; consequently each species appeared to fluctuate independently of the other (Fig. 2). Such specific differences may be illustrated by the drastic decline of the silverjaw minnow, *Ericymba buccata*, at a time of peak abundance of the bluntnose minnow, *Pimephales notatus*. The bluntnose produced a very strong 1952 year class which first entered the collections in October 1952, and comprised about three-fourths of the total number of this species taken. This year class accounted for the extreme abundance of this minnow the following summer. In the same year (1952) that reproduction of the bluntnose was especially successful, the silverjaw minnow established only a weak brood. As a result, the population of silverjaws suffered a sharp decline, seen first in October 1952, when young-of-the-year silverjaws comprised a percentage of the population much lower than was to be expected at this time of the year. The following August the silverjaw minnow population was at a level of abundance that was extremely low when compared with their populations the two preceding years, August 1951 and August 1952. Conditions for reproduction in 1953 were suitable for both species. Young bluntnose minnows were abundant in the fall collection, as were young silverjaw minnows which comprised almost the entire collection of this species in October. This abundance resulted in a strikingly sharp increase in numbers and a sudden drop in average size (Fig. 2).

The short life cycle, great reproductive potential, and rapid growth rate of minnows minimized the effects of cropping their populations. The collections made in Jordan Creek with the electric shocker tended simply to reduce the abundance of each brood of minnows ahead of its natural period of decline. The effects of continuous cropping with the electric shocker varied with the species of minnow, and depended largely on the period of breeding, rate of growth, and relative size of the species. Despite this differential action of the shocker, no species of minnows disappeared from the population. The use of $\frac{1}{4}$ -inch mesh nets for collecting the stunned fish restricted the harvest largely to minnows above 1.8 inches in length and even this size was not taken in proportion to its actual abundance in the population. Because of this selectivity, the larger species, for example the stoneroller, *Camptostoma anomalum*, appeared in the collections at an earlier period in their life cycle than did smaller species, such as the silverjaw minnow. Among species of similar sizes, those spawning early in the season entered the collection in August, whereas those spawning later were not taken in significant numbers until October. Cropping in August bore heavily on the yearling bluntnose and silverjaw minnows and this selective collecting reduced the average weight of individuals remaining in the stream (as is demonstrated by October collections). In contrast, the August collecting took young-of-the-year stonerollers about as effectively as it did the older age groups, consequently the average weight of individuals of this species increased the following October (Fig. 2). This relationship of abundance and average weight for the stoneroller followed a regular pattern throughout the nine collections taken in the experimental area of Jordan Creek.

COMPARISON OF SHOCKING AND SEINING OF MINNOWS

Since this investigation was in part concerned with the effects of commercial seining on natural minnow populations, the question obviously arises as to the relative efficiency of seining with legal minnow seines and shocking with the electrical apparatus as used in Jordan Creek. Under ideal seining conditions—smooth, even bottom with no snags, large boulders, ledges, or undercut banks—seining might be very efficient. Because the minnow seiner must look for such an ideal situation, his collecting is limited to an occasional pool throughout the reaches of most streams. In contrast, the use of the shocker is not so restricted by physical obstacles. The entire water area, every pool and shallow riffle, was carefully worked in this section of Jordan Creek, and because of this complete coverage it is believed the electrical method was many times more effective in this habitat than seining would have been.

With seining so restricted by physical conditions of the habitat, how are natural minnow populations damaged by seining? And if shocking is more efficient than seining, why has not the extensive collecting in Jordan Creek destroyed the minnow population, rather than allowing an increase in yield? Inasmuch as damage to minnow populations by seining has been reported by competent biologists (Markus, 1934, 1939; Surber, 1940; and others), the conditions under which seining might be detrimental to natural stream populations should be pointed out here. Principal among these conditions are the following:

1. Isolation of the cropped area so that there could be no recruitment of minnows through movements from adjacent areas—a series of dams, natural obstructions, or low water levels.

2. A habitat allowing complete seining of an extensive section of stream, such as a dredge ditch.

3. Year-around conditions favorable to seining, such as the absence of ice cover and/or high water levels, coupled with a continuing demand for minnows.

4. Changes in habitat resulting from pollution, dredging, or improper land use practices.

5. Low productivity, resulting from low natural fertility of the water and a short growing season.

That seining is responsible for the destruction of minnow populations in streams should not be assumed without an examination of all factors that might possibly influence the population. So far in Jordan Creek the natural fluctuations of the minnow population have been so great as to obscure the effects of cropping with the electric shocker, but to date no evidence of adverse effects has been obtained.

ACKNOWLEDGMENTS

This investigation is part of a cooperative project between the Illinois Natural History Survey and the Illinois Department of Conservation. The work of collecting, sorting, and tabulating these large collections of minnows was shared by many

people, but the major assistance was given by Leonard Durham, Quentin H. Pickering, James F. Opsahl, and William Childers of the Department of Conservation, and David W. Menzel, W. Leslie Burger, and William Nuess of the Natural History Survey.

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PHYSICO-CHEMICAL CHARACTERISTICS OF PONDS IN THE PYATT, DESOTO, AND ELKVILLE STRIP MINED AREAS OF SOUTHERN ILLINOIS ¹

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ABSTRACT

The physico-chemical characteristics of ponds of three strip-mine areas in Southern Illinois were observed under both winter and summer conditions. In addition to a general discussion of the areas, a detailed report is made on dissolved oxygen as associated with thermal stratification, and on pH and specific conductance. Observations were also made on the plant life and fishes of the ponds. The more important findings included high concentrations of dissolved oxygen in the thermocline, pH values ranging from 3 to 8, and extremely high specific conductance. Chemical conditions were not associated with the age of the ponds. The ponds have many characteristics of oligotrophic lakes and the possibilities for fish production are limited. The most common fishes of the ponds were the green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), and largemouth bass (*Micropterus salmoides*). Some ponds were devoid of fish life.

INTRODUCTION

There is a total of 21,700 acres of strip-mined land in the southern part of Illinois. On the Pyatt area, the principal concern of the present work, water area constitutes 4.5 percent of the total of 3,530 acres. The 155 acres of water of the Pyatt area are divided into approximately 50 pools ranging from a fraction of an acre to 16 acres (Fig. 1).

Fishery biologists, working in localities where stripped land occurs, are frequently asked about the possibilities of managing these waters for the production of fish. The present study was aimed at obtaining basic information that might be helpful in formulating fishery-management policies for such waters.

The areas chosen for study are identified as the Pyatt, Desoto, and Elkville areas. The Pyatt area is the largest and was given the most emphasis. Of the total of 50 ponds, on the Pyatt area, 14 of the larger ones were chosen to be considered in detail. Four ponds in the Elkville area and three in the Desoto area were studied.

METHODS

Preliminary observations of chemical and thermal stratifications were made during the summer of 1953. The data acquired agreed with those obtained in the formal samplings of the summer of 1954. To simplify pre-

¹ This study was sponsored jointly by the Traux Traer Coal Mining Company, Illinois Coal Strippers Association, Sport Fishing Institute, Illinois Department of Conservation, and Southern Illinois University.

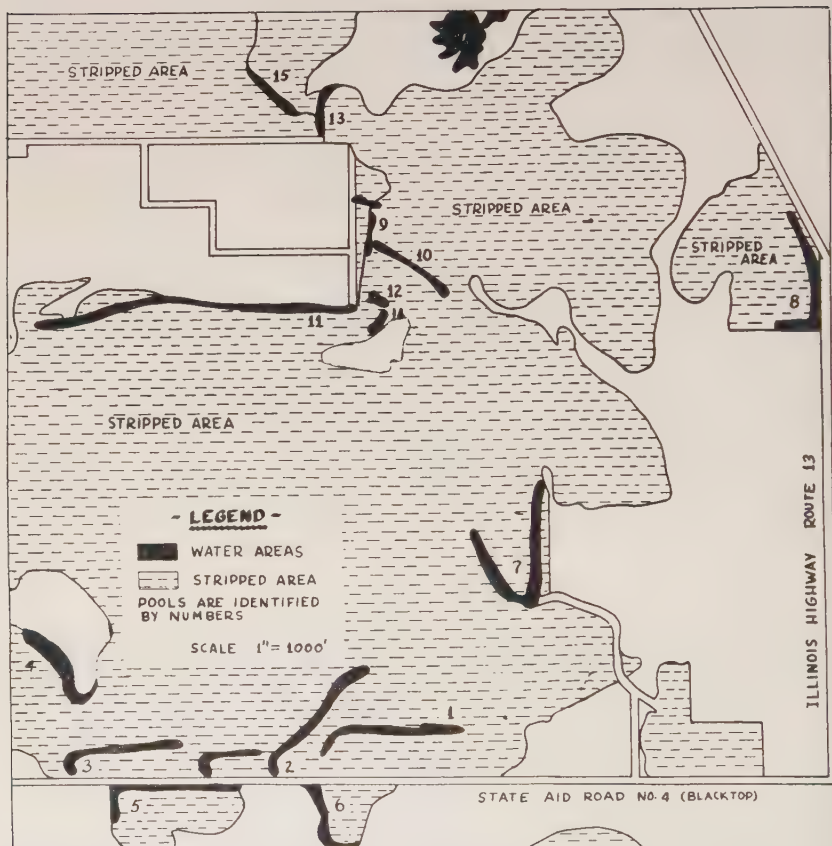


FIGURE 1.—Part of Pyatt strip-mine area, Perry County, Illinois, showing location of the ponds studied.

sentation, results of the preliminary observations are not given in the present work. Collection of the present data was carried out in February and March 1954 to represent winter conditions, and July 1954 to represent summer conditions. Observations were made of vertical distribution of temperature and dissolved oxygen and on specific conductance, turbidity, bottom precipitates, plant life, and fishes. Temperatures, determined by use of a maximum and minimum thermometer, were recorded at 3-foot intervals. To establish the exact location of the upper limit of the thermocline, readings at 1-foot intervals were made at the beginning of temperature change.

The pH was measured by a Beckman pH-meter. Total acidity was determined by NaOH titration. Because of the interference of highly ionizable salts, the determination of total acidity was abandoned. Dissolved

oxygen, determined by the Winkler method, was recorded at 7-foot intervals so as to reveal its relationship to thermal stratification. Specific conductance was obtained by use of a conductivity bridge. Turbidity was determined by use of a Jackson turbidimeter. The nature of the aquatic flora was established by collection and identification. The fishes present were determined by repeatedly scouting the shoreline of each pond and recording the species and numbers observed. The clarity of the water made this procedure possible. In fact, after experiments with shocking, seining, and trapping it was concluded that visual count was a more accurate means of determining the presence or absence of the various species. The acreage of all land and water areas was determined from an aerial photograph by use of a planimeter.

CHARACTERISTICS OF THE PONDS

Topography.—Stripped areas are extremely rough, as exemplified by Figure 2, which shows a typical pool on the Pyatt area and by the aerial photograph in Figure 3. Most of the pools are 20 to 30 feet deep with precipitous shorelines and few shallow areas. The steep shores extend up to 20 to 30 feet above the water surface in the form of spoil banks, which make the waters rather inaccessible. The watershed of the Pyatt and



FIGURE 2.—Typical pond of the Pyatt stripped area.



FIGURE 3.—Aerial view of a portion of the Pyatt stripped area.

Elkville areas is sparsely covered with a volunteer growth of cottonwood (*Populus deltoides*), sweet clover (*Melilotus alba*), wild lettuce (*Lactuca scariola*), goldenrod (*Solidago* spp.), and cheat (*Bromus secalinus*). Some small pine are also present. The Desoto watershed lacks vegetation.

Age.—The age of the ponds ranged from 4 to 30 years at the time of the survey. Apparently no particular correlation exists between age and other characteristics. The nature of the exposed spoils is probably more important than age in determining the chemical characteristics of the water.

Temperatures.—Winter temperatures taken at 3-foot intervals in the various ponds ranged from 36° to 50° F. Readings in the upper 6 to 9 feet varied slightly with air temperature and the ponds were not thermally stratified. Summer observations demonstrated thermal stratification in most of the ponds (Table 1). The upper limits of the thermocline started at 6 to 18 feet. The variation in depth of the upper limit of the thermocline probably was related to surface area and exposure. The lower limit of the thermocline was often poorly defined and many of the ponds had no hypolimnion. However, ponds such as Elkville Nos. 2 and 3 had sharp lower limits to their thermoclines and extensive hypolimnions.

Hydrogen-ion concentration.—The pH of the ponds exhibited some unusual differences (Table 2). The majority of the ponds are slightly basic, but some are extremely acid. The chemical nature of the waters is prob-

TABLE 1.—*Temperatures of Illinois strip ponds of the Pyatt, Elkhville, and Desoto spoil areas during July 1954*

Pond		Area (acres)	Temperatures °F. at depth in feet										
			S ¹	3	6	9	12	15	18	21	24	27	30
Pyatt	1.....	13.8	73	84	85	85	85*	75	67	66	62	61	60
	do. 2.....	8.3	73	82	82*	78	59	55	55	54	..	..	..
	do. 3.....	6.3	70	83	85	85	85	85*	75	68	63	57	55
	do. 5.....	14.4	71	84	84	85	85	85	85*	69	65	60	58
	do. 6.....	4.5	74	84	85	85	85	85	85*	75	..	..	..
	do. 7.....	16.3	75	84	84	84	84	84	..	..	..	..	..
	do. 8.....	5.0	82	84	84	84	84*	79	73	68	61	..	..
	do. 9.....	1.4	75	84	81	81	81	81	..	..	..	..	..
	do. 10.....	4.5	75	82	82	82	81	81*	79	75	72	72	67
	do. 11.....	4.5	82	85	85	85	85	85*	72	..	..	..	..
	do. 12.....	0.8	88	84	84	84	84*	79	..	..	..	..	..
	do. 13.....	5.8	85	84	84	84	84	84	84*	75	72	68	62
	do. 14.....	2.5	85	87	87	87	87*	76	..	..	..	..	..
	do. 15.....	4.9	85	84	84	84	84	84*	76	..	..	..	..
	Elkville	1.....	4.0	84	84	84*	80	..	..	..	..	..	..
do. 2.....		0.8	71	82	84*	74	64	60	54	54	52	51	49
do. 3.....		1.2	70	83	84*	70	62	60	60	58	58	57	..
do. 4.....		6.0	84	85	85	86	86	86*	77	71	67	65	62
Desoto	1.....	16.0	83	86	86	86*	74	67	..	..	..	..	..
	do. 2.....	0.1	80	85	86	86	..	..	..	..	..	..	..
	do. 3.....	0.6	80	86	86	86	86*	81	72	..	..	..	..

* Asterisk shows approximate upper limit of thermocline. See Table 3 for exact upper limit.

¹ SurfaceTABLE 2.—*The age, specific conductance, and pH of surface waters from strip ponds of Pyatt, Desoto, and Elkhville spoil areas during February or March 1954 and July 1954*

Pond	Approximate age of pond (years)	Specific conductance at 25° C. (reciprocal megohms)		pH	
		February or March 1954	July 1954	February or March 1954	July 1954
Pyatt 1.....	10	3,676	3,650	7.8	7.8
do. 2.....	11	3,546	3,650	7.7	7.7
do. 3.....	13	2,674	2,597	7.2	7.6
do. 5.....	20	2,217	2,883	5.5	6.1
do. 6.....	21	1,661	1,748	3.5	5.2
do. 7.....	5	3,257	3,559	7.6	7.4
do. 8.....	21	2,421	2,747	7.9	7.8
do. 9.....	10	2,128	2,747	3.3	5.4
do. 10.....	10	2,421	2,916	7.8	7.6
do. 11.....	10	982	1,577	7.6	7.7
do. 12.....	10	1,984	1,119	7.7	7.8
do. 13.....	8	2,833	3,448	4.0	5.3
do. 14.....	10	855	907	8.0	7.9
do. 15.....	8	2,083	2,092	7.2	7.2
Elkhville 1.....	30	2,000	2,404	6.5	7.6
do. 2.....	30	3,145	3,311	7.8	7.6
do. 3.....	30	3,257	3,311	8.0	7.4
do. 4.....	30	2,370	2,404	7.6	7.2
Desoto 1.....	4	3,817	3,846	8.0	7.0
do. 2.....	4	1,901	2,801	4.0	3.0
do. 3.....	4	3,937	4,167	8.1	7.0

ably controlled by the composition of the exposed spoils. The spoil banks include a mixture of limestone, pyrites, and other active minerals.

Dissolved oxygen.—The occurrence of dissolved oxygen in the cold water of the lower thermocline during the summer is one of the most interesting findings of the present study (Table 3). The majority of the ponds had ample oxygen in their lower waters to support fish. In five ponds (Table 3) the oxygen concentration was higher in the lower thermocline than in the epilimnion. This condition resulted from heavy plant growth on the bottom of these ponds. The presence of oxygen in the lower waters can be interpreted as resulting from clear water which permits light penetration and photosynthesis in the thermocline.

Turbidity.—At no time during the winter or the summer sampling was any pond observed to have a turbidity as high as 25 p.p.m. In the summer some of the ponds of neutral and high pH had enough algal growth to give the water a greenish tinge.

TABLE 3.—*The vertical distribution of dissolved oxygen in Illinois strip ponds of the Pyatt, Elkville, and Desoto spoil areas, during July 1954*

Pond	Upper limit of thermocline (feet)	Dissolved oxygen (p.p.m.) at various depths (feet)					Maximum depth (feet)
		1	8	15	22	Bottom	
Pyatt 1.....	13	8.1	8.1	8.7	8.1	6.0	30
do. 2.....	8	10.0	0.4	0.0	0.0	....	25
do. 3.....	16	8.7	8.7	9.1	6.0	2.3	30
do. 5.....	19	8.0	8.0	9.8	9.8	0.0	36
do. 6.....	20	9.0	9.0	8.9	1.2	....	22
do. 7.....	none	8.9	9.0	2.9	....	....	15
do. 8.....	15	10.2	10.2	13.2	4.1	....	23
do. 9.....	none	8.0	8.0	8.0	....	....	15
do. 10.....	18	9.7	9.7	18.2	19.7	7.6	37
do. 11.....	16	9.6	9.6	15.5	14.9	....	22
do. 12.....	13	9.1	9.1	3.4	....	....	16
do. 13.....	19	7.9	7.9	7.9	9.8	10.9	32
do. 14.....	14	7.8	7.9	1.9	....	....	15
do. 15.....	16	9.3	9.4	18.1	....	....	18
Elkville 1.....	8	9.1	1.9	....	....	....	8
do. 2.....	8	10.4	17.1	10.7	1.4	0.0	35
do. 3.....	7	10.9	17.5	0.5	0.5	0.0	28
do. 4.....	18	8.4	8.4	8.3	12.5	10.4	28
Desoto 1.....	11	9.2	2.2	0.0	....	....	15
do. 2.....	none	9.3	9.3	....	....	....	9
do. 3.....	15	7.8	8.1	10.8	5.4	....	19

Specific conductance.—One of the outstanding characteristics of strip mine water is a high salt content (Table 2). The specific conductance ranged from 900 to 4,000 reciprocal megohms. These values may be considered as high (Ellis, Westfall, and Ellis, 1948). The values were well above those characteristic of farm ponds in the vicinity of the strip mines. The specific conductivity of four farm ponds in the Pyatt area ranged from 100 to 250 reciprocal megohms.

Precipitates.—Precipitated ferric oxide occurred in 4 of the 14 Pyatt ponds (Nos. 5, 6, 9, and 13) and, to a lesser extent, in Desoto No. 2. These ponds were those characterized by a low pH (Table 2). The occurrence of the precipitate is correlated with a low pH value. Pyatt pond No. 2 and Elksville Nos. 2 and 3 contained a precipitate of ferric sulfide.

Water color.—Ponds with low pH values were easily recognized by their peculiar color. Some of them had a crystalloidal green color, while others were turquoise. Ponds with pH values above 7 were colorless.

Aquatic vegetation.—Pyatt ponds Nos. 5, 6, 9, and 13 and Desoto pond No. 2, the ponds with very low pH values, had no submerged or floating vegetation. Cattail (*Typha latifolia*) was common around the edges of all but two ponds. The narrow-leaved pondweed (*Potamogeton foliosus*) was abundant in all ponds with average or high pH values. Stonewort (*Chara fragilis*) was found in many of the ponds having high pH values (Pyatt Nos. 2, 3, 10, 12, and 14).

Chance introduction and water depth were probably also important in the occurrence and extent of vegetation in the ponds with normal or high pH values.

Fishes.—The green sunfish and bluegill were abundant in 13 of the 21 ponds studied. The largemouth bass occurred in 5. Some ponds did not have a fish population (Pyatt Nos. 1, 6, 7, 9, 10, and 13, and Desoto No. 2). Pyatt No. 5 had only a few small green sunfish.

Since a strip-mine pond is devoid of fish at the time of formation and since the ponds are usually rather isolated, the occurrence of various species of fish is not altogether a matter of the nature of the habitat. Involved also is the matter of introduction. It is certain, however, that no fish were found in those ponds with very low pH values. The failure of fish to occur in Pyatt ponds Nos. 1, 7, and 10 does not appear to be explainable on basis of chemical conditions. It seems probable that fish simply have not been introduced into these ponds.

POSSIBILITIES FOR FISH PRODUCTION

Possibilities for the production of fish in strip mine ponds are highly impractical—in some ponds impossible—due to such conditions as high acidity, high salt content, or low fertility. Even when fish can be produced, their utilization is often limited because of the inaccessibility and steepness of the shorelines of the ponds. Furthermore, the application of management policies is handicapped by the circumstances that the ponds cannot be drained, and, usually, because of their depth, they cannot be seined successfully.

Few of these ponds suffer from all of these disabilities but one or more of these conditions reduce the potentials of the waters of the stripped area. Some of the limitations can be overcome, but it is questionable if

this is economically feasible. Nevertheless, 5 of the 21 ponds considered here are producing acceptable fishing. Others probably would produce fishing if they were heavily stocked with largemouth bass fingerlings too large to be eaten by the green sunfish.

On the other hand, the strip mine ponds offer some rather interesting possibilities. Most of the ponds are thermally stratified, and most of them have oxygen in the cooler water of the thermocline and hypolimnion. It is thus conceivable that a few of them might support brown trout (*Salmo trutta*), rainbow trout (*S. gairdneri*) or smallmouth bass (*Micropterus dolomieu*). In the southern Illinois area these fishes would be a novelty and would stimulate much interest.

ACKNOWLEDGMENTS

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NUMERICAL ABUNDANCE AND USE OF A SPAWNING RUN OF WALLEYES IN THE MUSKEGON RIVER, MICHIGAN¹

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ABSTRACT

During March and April of 1953 and 1954 walleyes were tagged and released in Muskegon Lake before they ascended the Muskegon River on a spawning migration. Recoveries of the tagged walleyes were made by dip nets below Newaygo Dam 39 miles upstream. Estimates of the numerical abundance of the spawning runs computed from these recaptures (ratio of tagged to untagged walleyes in the dip-net catch) were about 114,000 individuals in 1953 and about 139,000 fish in 1954.

From the population estimates it was determined that transfer of between 7,000 and 8,000 walleyes to reservoirs above Newaygo Dam did not involve a large percentage of the total run. Of the walleyes that were not transferred, about 9,000 to 11,000 were captured by anglers; the cropping rate, therefore, was small.

INTRODUCTION

Walleyes, *Stizostedion vitreum vitreum* (Mitchill), from Lake Michigan annually enter the Muskegon River by way of Muskegon Lake on a spawning migration (Fig. 1). A hydroelectric dam, at the village of Newaygo, about 39 miles above the river mouth, prevents continued upstream progress by the migrating walleyes. Other dams and their associated reservoirs are located upstream from Newaygo.

Years ago, fishermen interested in the Muskegon River walleyes realized that the Newaygo Dam was possibly interfering with the spawning migration, and that the barrier might have an adverse effect on the sport fishing in the various upstream impoundments by preventing mature walleyes from reaching them. The idea of transporting a portion of the fish in the spawning run to the various upstream impoundments was thus conceived. Each year since 1923, varying numbers of walleyes, usually some thousands, have been captured by dip nets from the river below Newaygo Dam, transported by tank trucks to upstream areas, and released. This operation, which is known as the "Newaygo Transfer" has been closely supervised since 1928 by the Fish Division of the Michigan Department of Conservation.

Since its inception the transfer has been a controversial issue. Anglers who do most of their fishing in the river below Newaygo, or in Muskegon Lake, insist that the operation is unnecessary and detrimental. Anglers

¹ Contribution from the Institute for Fisheries Research.

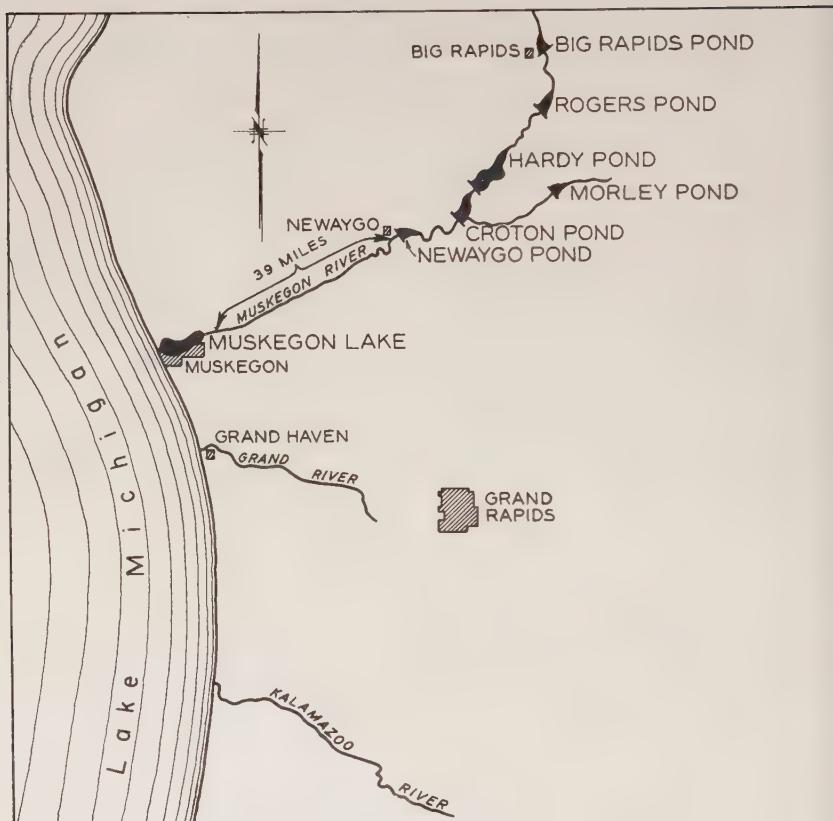


FIGURE 1.—Lower Muskegon River Area.

who fish in the upstream impoundments insist that the transfer is necessary and entirely beneficial.

In 1936, in an effort to resolve the controversy between the two factions, the Department of Conservation placed certain arbitrary restrictions on the transfer. A limit of 10,000 fish or 15 nights of dip netting was imposed, and the transfer for that particular year was terminated when either condition was satisfied. These restrictions were satisfactory for a while, but the controversy has again become active, and the transfer was the subject of litigation as recently as 1952. The interest generated by the transfer and the walleye fishery on the Muskegon River made it imperative that the Fish Division should conduct a thorough study of the whole situation. This investigation has been pursued more or less intensively since 1947. Results have been presented by Eschmeyer (1950) and by Eschmeyer and Crowe (1955), but to the present time little information has been presented on the numerical abundance, percentage of the run involved in the transfer,

or extent of utilization by anglers. Information obtained on these points during 1953 and 1954 is reviewed in this paper.

METHODS

Evidently, knowledge of the numerical abundance of the spawning run was of paramount importance. With such information it would be possible to determine what percentage of the run is involved in the transfer, extent of harvest by anglers, and whether the restrictions presently in effect are just and proper. Walleyes from Lake Michigan enter Muskegon Lake and congregate near the entrance of the Muskegon River prior to their upriver migration. If a fairly large sample of these fish could be marked before they moved upstream, it would be possible to obtain recoveries later at Newaygo Dam while the transfer was in progress. The time lapse between marking in Muskegon Lake and recovery at Newaygo Dam should permit marked walleyes to become mixed with unmarked. Consequently, in the springs of 1953 and 1954 fairly large samples of walleyes were captured, tagged, and released in Muskegon Lake prior to their migration upstream. In both years a commercial seiner was hired to capture the walleyes for tagging, and his efforts were supplemented by the use of trap nets operated by department personnel. Walleyes tagged in Muskegon Lake were measured and, when possible, sex was determined by extruding eggs or milt, (a few large individuals were considered to be females on the basis of size alone). Individuals whose sex was not readily recognizable were recorded as of undetermined sex. Date of tagging and release was also noted. Information on length and sex was recorded to permit later comparison between tagged and untagged individuals as an aid in determining whether the tagged sample was representative of the fish in the spawning run. All of the walleyes for tagging were captured in Muskegon Lake, and all recovery data used in population estimates were secured from the dip-netting site below Newaygo. Data on rate of exploitation in the sport fishery have been based on information obtained through the cooperation of anglers who reported the capture of tagged walleyes during 1953 and 1954. Information on the commercial fishery has been derived from tag returns and from catch data compiled by Great Lakes Fishery Investigations, U. S. Fish and Wildlife Service.

THE 1953 INVESTIGATION

In 1953, 676 walleyes were tagged and released in Muskegon Lake between March 13 and March 31 (see Fig. 2 for fishing localities). Most of the tagged fish were captured by seine, and released at the east end of the lake, near the entrance of the Muskegon River. However, about 25 percent of the tagged fish were caught in trap nets and released at the west end of the lake near the outlet.

The Newaygo Transfer in 1953 took place between April 4 and April 18, during which period all walleyes captured in dip nets were examined for tags. Since each walleye captured had to be handled, it was possible

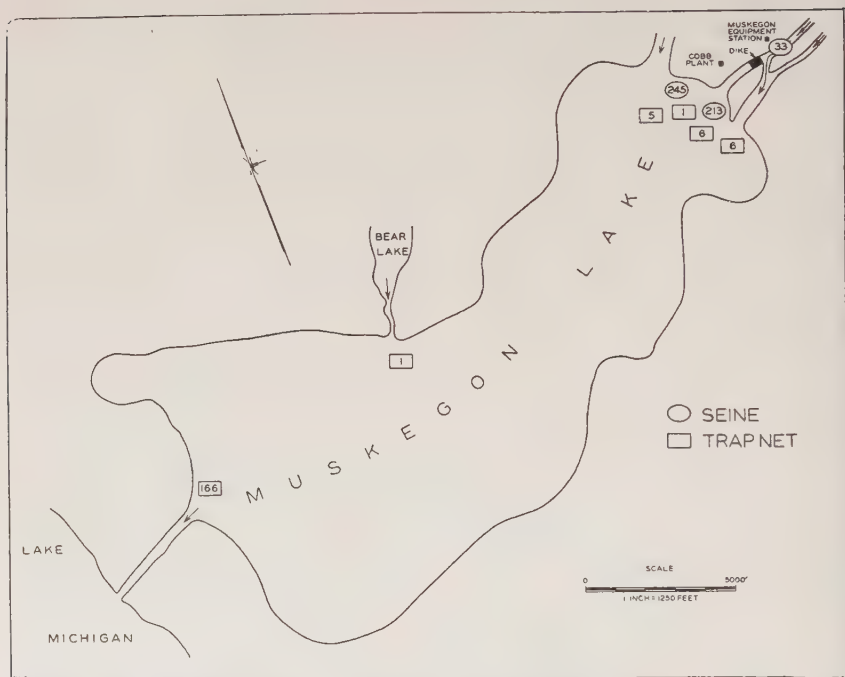


FIGURE 2.—Diagrammatic map of Muskegon Lake showing method of capture and points of release for 676 walleyes tagged in 1953. [Figures within symbols are numbers of walleyes tagged.]

to measure and determine sex of a large sample of the unmarked specimens. Length and sex were determined for 29 percent of the walleyes captured for transfer. The sample included a portion of the walleyes captured on each day of the transfer and also some fish from each dip-net site; thus the measured sample was doubtless representative of the 7,661 walleyes transferred. Whether the transferred fish are equivalent in all respects to the fish congregated in the vicinity of Newaygo Dam is not known, but we have no reason to suspect otherwise, except that possibly females are more vulnerable to the dip nets than are males.

The comparison of walleyes tagged at Muskegon Lake with those captured at Newaygo, by length and by sex ratio (Table 1), at once reveals two differences. First, tagged males were larger than untagged males. The difference between the mean lengths of the two lots is statistically significant (t test) at the 95-percent level. The greater length of the tagged males is readily explicable, however, on the basis of gear selectivity. Most of the walleyes for tagging were captured by a seine with sufficiently large mesh to permit escape by smaller individuals, most of which were doubtless males. The dip nets at Newaygo are of small enough mesh to hold small walleyes. The length distributions and average lengths of the two groups

TABLE 1.—Comparison of tagged with "transferred" walleyes by length distribution, mean length, standard error of mean length, and sex ratio in 1953

Total length (inches)	Male		Female		Undetermined sex		All	
	Tagged	Transferred	Tagged	Transferred	Tagged	Transferred	Tagged	Transferred
11-11.9.....	..	..	..	..	4	2	4	2
12-12.9.....	..	..	..	..	3	1	3	1
13-13.9.....	1	8	..	..	7	1	8	9
14-14.9.....	5	45	..	1	5	1	10	47
15-15.9.....	9	117	..	..	12	..	21	117
16-16.9.....	29	321	5	6	11	..	45	327
17-17.9.....	52	359	24	44	40	..	116	403
18-18.9.....	39	172	60	159	33	1	132	332
19-19.9.....	16	43	85	327	31	..	132	370
20-20.9.....	7	12	79	273	6	1	92	286
21-21.9.....	12	19	29	136	2	..	43	155
22-22.9.....	10	18	17	54	..	..	27	72
23-23.9.....	3	7	6	33	..	..	9	40
24-24.9.....	..	3	8	23	..	..	8	26
25-25.9.....	1	1	5	17	1	..	7	18
26-26.9.....	..	..	6	18	..	..	6	18
27-27.9.....	..	..	8	9	..	..	8	9
28-28.9.....	..	..	2	8	..	..	2	8
29-29.9.....	..	..	1	2	..	..	1	2
30-30.9.....	..	..	1	..	..	..	1	..
Number.....	184	1,125	336	1,110	155	7	675	2,242
Mean.....	18.3	17.3	20.3	20.4	17.5	14.6	19.1	18.8
Standard error.....	0.16	0.05	0.13	0.06	0.18	1.24	0.10	0.05
Percentage ¹	27.2	50.2	49.8	49.5	23.0	0.3	100.0	100.0

¹Percentage of total sample of tagged or untagged fish of indicated sex

of females, on the other hand, were closely similar. The second difference between the two lots of fish which concerns the distribution of the sexes may depend on the fact that 23 percent of the tagged walleyes were of undetermined sex. If, as the length distribution suggests, the walleyes of undetermined sex were mostly males, then the sex ratios of the two lots are more nearly identical. For the sexes combined the two lots of fish were similar in length distribution and average length.

During the 1953 Newago Transfer 42 of the 7,661 walleyes captured had been tagged in Muskegon Lake. The pattern of the returns clearly indicated that tagged fish were mixed with untagged fish during the whole transfer (Tables 2 and 3). Analysis of the recaptures of tagged walleyes also revealed that fish released at either the east or west ends of Muskegon Lake reached Newago while the transfer was in progress, and that walleyes were able to make the 39-mile trip from the lake to the vicinity of Newago Dam quickly enough to become available to the dip nets from the start of the operation. The average number of days required for walleyes to make the trip and be captured by a dip net below Newago was 20.9 days (range, 11 to 35 days, standard deviation, 5.09 days).

If the size of a population is to be computed from a ratio of marked to unmarked individuals in samples drawn from that population, certain requirements must be satisfied. The population must remain relatively

TABLE 2.—Daily record of walleye catch and tag recoveries during "Newaygo Transfer", April 4 to April 18, 1953

Date	Dip-net catch	Number of tags recovered	Date	Dip-net catch	Number of tags recovered
April 4.....	569	1	April 13.....	597	4
do. 5.....	627	2	do. 14.....	357	2
do. 6.....	704	2	do. 15.....	279	6
do. 7.....	597	4	do. 16.....	297	..
do. 8.....	797	..	do. 17.....	145	3
do. 9.....	585	4	do. 18.....	106	..
do. 10.....	715	6			
do. 11.....	401	3	Total.....	7,661	42
do. 12.....	885	6			

TABLE 3.—Number of recoveries at Newaygo Dam from each day of tagging in Muskegon Lake

Date of tagging	Number tagged	Number recovered	Percentage recovered	Date of tagging	Number tagged	Number recovered	Percentage recovered
March 13.....	33	2	6.1	March 25.....	11	1	9.1
do. 16.....	5	1	20.0	do. 26.....	7	..	..
do. 17.....	129	11	8.5	do. 27.....	26	1	3.8
do. 18.....	70	10	14.3	do. 28.....	28	..	..
do. 19.....	4	..	..	do. 29.....	30	..	..
do. 20.....	3	..	..	do. 30.....	229	9	3.9
do. 21.....	35	5	14.3	do. 31.....	23	..	..
do. 22.....	6	1	16.7				
do. 23.....	11	1	9.1	Total or average.	676	42	6.2
do. 24.....	26	..	..				

stable during the period of the estimate, and either the marked fish must be randomly distributed through the whole population or the sampling must be unbiased. In this investigation the first requirement was probably satisfied, for the spawning run of walleyes may be regarded as homogeneous. It is composed entirely of mature fish from Lake Michigan engaged on a spawning migration. The second requirement (even mixing of marked fish or unbiased sampling) was not completely satisfied, for analysis of tag returns revealed that the rate of recapture was influenced by time of tagging. The percentage of recapture from those walleyes which were tagged and released in Muskegon Lake early in the tagging period was higher than it was for those tagged and released later. It is shown later that the existing bias was not of sufficient magnitude to influence results strongly.

Numerous methods have been described for estimating the size of animal populations from the ratio of marked to unmarked individuals. In this investigation estimates were made by four different procedures. By the method described by Schnabel (1938) an estimate of 119,724 fish was obtained, and when the method described by Schumacher and Eschmeyer (1943) was used an estimate of $120,807 \pm 19,402$ resulted. The direct proportion, or Peterson method, gave 123,306. Schaefer (1951) described a method which seems particularly applicable to this situation. In his abstract Schaefer said, "For some migratory fishes, which are marked at

a point on their migration path, and sampled at some other point, there exists, when the migration extends over a considerable space of time, a correlation between time of tagging and time of recovery at the point of subsequent sampling. In such cases, the total number of fish marked or drawn in subsequent samples cannot in general be regarded as random samples of the whole population. Where numbered tags are used to mark individuals, so that they may be identified individually both when tagged and when recovered in the samples, a method of estimating N is suggested." Through the use of Schaefer's method an estimate of 113,882 was obtained. This estimate is considered to be the "best" of the four. The difference (about 6,000) between the estimate obtained through the use of Schaefer's formula, and that obtained by other methods is small.

THE 1954 INVESTIGATION

The tagging of spawning walleyes was repeated in 1954 as a check on the validity of the 1953 results, and to obtain supplementary information. Methods were the same in both years and results were generally similar.

Between March 11 and April 6, 1954, 687 walleyes were tagged and released in Muskegon Lake. Again, most of the fish were released near the east end of the lake (Fig. 3). The 1954 Newago Transfer took place between April 6 and April 20. The measured sample (28 percent) of the transferred walleyes was doubtless representative of the walleyes captured by dip nets, for as in 1953, fish were measured each day, and from all dip-net sites. Again, it appeared that females may have been somewhat more vulnerable to dip nets than were males.

The comparison, by length and by sex ratio, of tagged walleyes with those captured at Newago (Table 4) demonstrates that in 1954, as in 1953, tagged males were significantly longer than males captured during the transfer. The 1954 difference also can be attributed to selective action of the different types of gear used to capture the different samples, and again most of the tagged walleyes of undetermined sex were probably males. The length distribution and mean lengths of females in the two lots were similar. For the combined sexes, differences between the two lots (tagged and untagged) were too small to influence population estimates to any great extent.

During the 1954 Newago Transfer 38 walleyes of that year's tagging were included in the total catch of 7,840 fish. In addition, there were 28 returns from walleyes that had been tagged and released in Muskegon Lake in 1953.

The returns in 1954, as in 1953, indicated that tagged fish were rather uniformly distributed among the untagged (Tables 5 and 6). As can be seen in Table 6, nearly all of the walleyes tagged were marked on March 18, March 24, and April 6 and all of the returns were of fish tagged on those dates. That some walleyes tagged on days other than March 18 and 24 and April 6 reached Newago is known, however, from anglers' reports of catching them in the vicinity of Newago Dam during and immediately

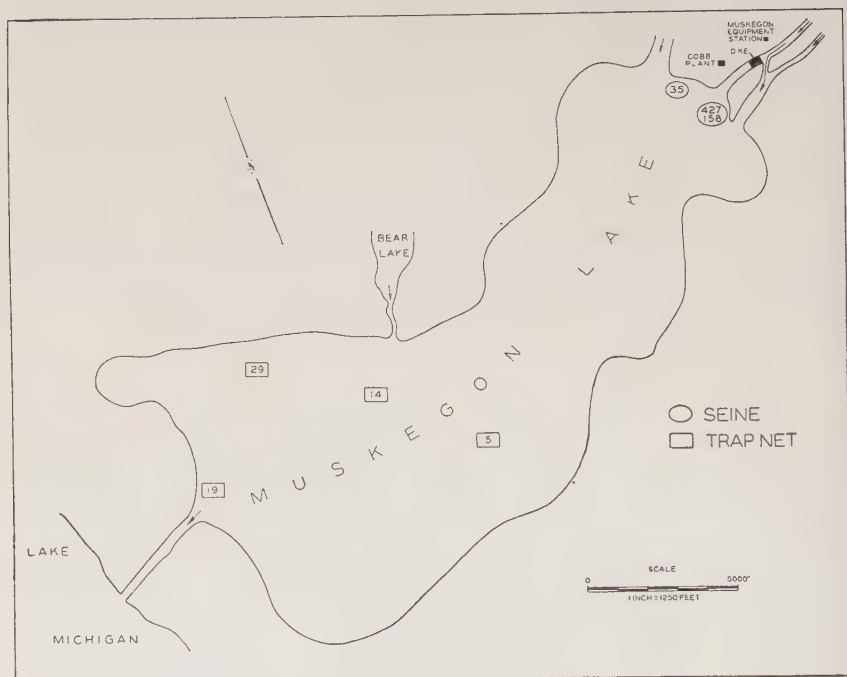


FIGURE 3.—Diagrammatic map of Muskegon Lake showing method of capture and points of release for 687 walleyes tagged in 1954. [Figures within symbols are numbers of walleyes tagged.]

after the transfer operation. The 1954 walleyes, like the 1953 fish, made the 39-mile trip from Muskegon Lake rapidly enough to be available to the dip nets while the transfer was in progress. In 1954 the average number of days required to make the trip was 18.5 (range 6 to 30 days, standard deviation 5.75 days). The lower average time between tagging and recapture of 1954 walleyes was probably caused by the later tagging.

As in 1953, basic requirements for estimation of the population seem to have been satisfied. The spawning walleyes were a homogeneous group of mature fish, and marked fish were mixed among them. Estimates accordingly were computed in the same manner as in 1953 (Table 7). In 1954, estimates by different methods agreed even more closely than they did in 1953. The 1954 estimate was higher, and I believe that there actually were more walleyes in the river. The larger population was composed of most of the same walleyes present in 1953, augmented by those which had grown to maturity during 1953. The belief is supported by analysis of tag returns from walleyes tagged in 1953. If the 676 walleyes tagged in 1953 are reduced by known loss (tagged fish transferred upstream or caught by anglers or commercial fisherman), there would remain 559 of them

TABLE 4.—Comparison of tagged with "transferred" walleyes by length distribution, mean length, standard error of mean length, and sex ratio in 1954

Total length (inches)	Male		Female		Undetermined sex		All	
	Tagged	Transferred	Tagged	Transferred	Tagged	Transferred	Tagged	Transferred
11-11.9.....	..	1	..	..	1	1	1	2
12-12.9.....	..	6	..	..	1	..	1	6
13-13.9.....	..	30	..	..	1	..	1	30
14-14.9.....	2	91	..	..	..	..	2	91
15-15.9.....	15	189	..	..	4	1	19	190
16-16.9.....	45	199	3	..	6	..	54	199
17-17.9.....	49	137	7	15	11	..	67	152
18-18.9.....	66	106	13	51	9	1	88	158
19-19.9.....	61	93	43	211	9	1	113	305
20-20.9.....	34	20	81	364	3	..	118	384
21-21.9.....	10	10	91	396	6	1	107	407
22-22.9.....	4	6	64	210	2	..	70	216
23-23.9.....	3	2	19	48	1	1	23	51
24-24.9.....	5	3	4	13	..	..	9	16
25-25.9.....	..	1	..	4	..	..	..	5
26-26.9.....	..	..	3	7	..	..	3	7
27-27.9.....	..	..	1	4	1	..	2	4
28-28.9.....	..	..	6	5	..	..	6	5
29-29.9.....	..	..	3	3	..	..	3	3
30-30.9.....	..	..	..	1	..	..	..	1
Number.....	294	894	338	1,332	55	6	687	2,232
Mean.....	18.6	16.8	21.3	21.1	18.5	18.3	19.9	19.4
Standard error.....	0.095	0.042	0.012	0.018	0.13	3.1	0.008	0.003
Percentage ¹	42.8	40.0	49.2	59.7	8.0	0.3	100.0	100.0

¹ Percentage of total sample of tagged or untagged fish of indicated sex

TABLE 5.—Daily summary of walleye catch and tag recoveries during "Newaygo Transfer", April 6 to April 20, 1954

Date	Dip-net catch	Recoveries of fish tagged in		Date	Dip-net catch	Recoveries of fish tagged in	
		1954	1953			1954	1953
April 6.....	362	1	1	April 15.....	546	6	1
do. 7.....	383	1	1	do. 16.....	664	5	1
do. 8.....	572	..	2	do. 17.....	344	2	..
do. 9.....	649	..	3	do. 18.....	274	3	2
do. 10.....	665	2	2	do. 19.....	155	2	..
do. 11.....	819	1	4	do. 20.....	109	..	..
do. 12.....	982	10	6				
do. 13.....	668	3	4	Total.....	7,840	38	28
do. 14.....	648	2	1				

which should have been available to dip nets during the 1954 transfer. If we assume that the fish tagged and released in Muskegon Lake in 1953 were equally vulnerable to the dip nets during 1954 as those tagged and released in Muskegon Lake in 1954, we would expect a return of 31 of the walleyes tagged in 1953. As can be seen in Table 5, 28 were recaptured. Obviously mortality (unknown loss) of mature walleyes was negligible during 1953. Also note (Table 4) that in 1954 the walleyes in the transfer

TABLE 6.—*Summary of recovery by dip nets at Newaygo of walleyes tagged in Muskegon Lake in 1954, showing number of recoveries from each day of tagging*

Date of tagging	Number tagged	Number recovered	Percentage recovered	Date of tagging	Number tagged	Number recovered	Percentage recovered
March 11.....	4	..	...	March 20.....	7	..	...
do. 12.....	21	..	...	do. 21.....	5	..	...
do. 14.....	6	..	...	do. 22.....	1	..	...
do. 15.....	1	..	...	do. 23.....	7	..	...
do. 16.....	1	..	...	do. 24.....	426	28	6.6
do. 17.....	6	..	...	April 6.....	158	8	5.1
do. 18.....	37	2	5.4				
do. 19.....	7	..	...	Total.....	687	38	5.5

TABLE 7.—*Tagging data and estimates of numerical abundance of spawning walleyes in the Muskegon River, Michigan, 1953 and 1954*

Item	1953	1954
Tagged in Muskegon Lake.....	676	687
Tagging period.....	March 13 to March 31	March 11 to April 6
Recovered at Newaygo.....	42	38
Percentage recaptured.....	6.2	5.5
Recovery period.....	April 4 to April 18	April 6 to April 20
Transferred to impoundments.....	7,661	7,840
Estimates;		
Schnabel (1938).....	119,724	139,327
Schumacher and Eschmeyer (1943).....	120,807 $\pm$ 19,402	140,344 $\pm$ 23,985
Schaefer (1951).....	113,882	138,776
Direct proportion.....	123,306	141,739
Percentage of run transferred.....	6.7	5.6

were, on the average, slightly larger than those in 1953 (19.4 inches compared to 18.8) which difference indicates growth throughout the whole population.

PERCENTAGE OF RUN TRANSFERRED

The 7,661 walleyes transferred in 1953 represented only 6.7 percent of the 113,882 fish theoretically available, and the 7,840 walleyes transferred in 1954 represented only 5.6 percent of the 138,776 fish presumably available. Obviously, restrictions presently in effect for the conduct of the transfer are conservative.

UTILIZATION OF THE SPAWNING RUN BY ANGLERS IN 1953 AND 1954

The walleye tagging in Muskegon Lake in 1953 and 1954 afforded an opportunity to obtain information on use of the spawning run of walleyes by anglers. During 1953, sport fishermen captured not fewer than 52 (about 8 percent) of the walleyes which had been tagged and released in Muskegon Lake in the spring. This information is based on voluntary tag returns submitted by anglers. It is not known whether all recaptures of tagged fish were reported, but the Muskegon River investigation has

created such great local interest and has had so much publicity that I believe most fishermen do report recoveries of tagged walleyes. From the recapture it may be estimated that during 1953 anglers caught about 9,000 of the walleyes that migrated up the Muskegon River to spawn. In 1954 anglers reported the recapture of 42 of the walleyes which had been tagged and released in Muskegon Lake in 1953. Thus, at the end of two seasons anglers had caught about 14 percent or 16,000 of the walleyes which migrated upriver in 1953. In 1954, anglers took 48 or 7 percent of the 687 walleyes tagged and released in Muskegon Lake during the spring of the same year; thus, it may be estimated that from the 1954 run about 11,000 walleyes were caught by fishermen that year. The rate of return from walleyes tagged in 1953 and 1954 was intermediate between that reported by Eschmeyer and Crowe (1955) for walleyes tagged and released in the Muskegon River below Newago in 1948 and 1950.

The recoveries give additional insight into the nature of the spawning run in the Muskegon River. Of the 52 recaptures in 1953, 11 were made outside the Muskegon River System—all of them after June 1. The remaining 41 tagged walleyes came from Muskegon Lake, or from the river below Newago Dam, and 27 of these were captured in April or May. This situation might be expected, for the walleyes are congregated in Muskegon Lake or in the Muskegon River at that time. Only 14 recaptures were reported from the lower Muskegon River between June 1 and December 31. The lower rate of returns in these months probably reflects poorer fishing, rather than lack of fishing pressure, for in Michigan most angling is done in mid-summer. Of the 42 recaptures made in 1954 of walleyes which had been tagged in 1953, only 2 were made outside of the Muskegon River System—one on May 30, and one on June 26. Of the 40 recaptures made in the Muskegon River System only 6 were captured later than June 1, 1954 which indicates that the best walleye fishing in the Muskegon River below Newago takes place before June 1. Of the 48 recaptures in 1954 of walleyes tagged in the spring of that year, 7 came from areas outside the Muskegon River System—all of them caught later than June 1. Of the remaining 41 recaptures, 32 were made in Muskegon Lake or the Muskegon River below Newago Dam prior to June 1, which tends to confirm the belief that the best fishing takes place in the lake and river before June 1, and that after June 1 many of the walleyes have left the lake and the river.

UTILIZATION BY COMMERCIAL FISHERMEN

During 1953, commercial fishermen reported the recapture of 5 of the walleyes which had been tagged and released in Muskegon Lake in 1953. In 1954, commercial fishermen reported the recapture of 3 more of these fish, and also of 11 of the walleyes which were tagged in the spring of 1954. From these figures it can be estimated that commercial fishermen caught about 1,350 (3,500 pounds) of the walleyes in the 1953 spawning run, and 2,200 from the 1954 run. The 1953 commercial catch of walleyes

from the eastern shore of Lake Michigan was 34,500 pounds, or about 13,500 walleyes (U. S. Fish and Wildlife Service files). The discrepancy between the estimated catch (based on tag returns) and the actual catch (based on compulsory reports) cannot be fully explained. Commercial fishermen, being less interested in the Muskegon River investigation, may, in many instances, have failed to report the capture of tagged walleyes. A second possibility is that commercial fishermen were exploiting, in part, a walleye population distinct from that which enters the Muskegon River.

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EFFICIENCY OF CHINOOK SALMON SPAWNING IN FALL CREEK, CALIFORNIA

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ABSTRACT

The spawning efficiency of chinook salmon (*Oncorhynchus tshawytscha*) in Fall Creek, a tributary of the Klamath River in northern California, was measured during four runs, 1950–1954, inclusive. In these years the following numbers of pairs of spawners were allowed to enter the stream: 750, 500, 300, and 300, respectively. Estimates of the total egg production of these fish were based on sampling. The numbers of downstream migrant fingerlings resulting from each of these spawning runs were computed by trapping the migrants in a known fraction of the stream flow. The percentages of potential eggs resulting in migrants leaving Fall Creek in the years sampled were 7, 10, 9, and 32, respectively. There appears to be an inverse correlation between the size of floods during incubation and the efficiency of spawning.

INTRODUCTION

The first attempt to increase the runs of Pacific salmon was made by Livingston Stone in 1872, at which time the Baird Hatchery was constructed on the McCloud River in California. This work was founded on the belief that fertilization in nature is poor and that, in common with other salmonids, the eggs and fry of the chinook salmon suffer very great mortalities during incubation in the stream gravel and shortly after their emergence. It was believed that through artificial propagation these problems could be largely overcome and the numbers of adults reaching the fishery thereby increased.

These assumptions were to a large extent correct and for the past 75 years salmon hatcheries have constituted the major effort toward conservation of the runs. However, it has not been demonstrated that these salmon hatcheries, as they have been operated in the past, are of great value in sustaining the yield. Discussion of the reasons for this failure is beyond the scope of this report, but it is theoretically possible to overcome these inadequacies.

Within recent years fishery biologists have become increasingly aware that populations of salmon are able to maintain their numbers in the face of a heavy fishery and without the benefit of artificial propagation. The investigations of Foerster (1936) and his colleagues at Cultus Lake best illustrate this point. The phenomenon of "resiliency", well known to students of population dynamics, and mentioned in relation to salmon by Thompson (1944, 1950) and by Pritchard (1948) and more recently

reviewed by Neave (1953), has now become an accepted part of fishery science. Resiliency means simply the ability of a species to compensate for losses. The work being conducted in British Columbia is outstanding with respect to the genus *Oncorhynchus*. The important species there are *gorbuscha*, *keta*, and *nerka*. Much less work has been done on *kisutch* and *tshawytscha*. Hobbs (1937) has obtained some figures on the reproductive efficiency of *O. tshawytscha*, but these data are not entirely comparable with those presented in this report.

Generally, all species of this group have much the same mortality pattern. Each breeding pair is replaced with a similar pair in the end, but there are variations with respect to mortalities in each stage of the life cycle. Some of these variations in the mortality pattern are characteristic of the species and others are probably inherent in the individual population. In one group the burden of the loss may fall during the egg stage, in another it may fall upon the alevins or upon the newly emerged fry. From the standpoint of number, the fresh-water period appears to be far more fateful than the salt-water existence.

A matter of considerable practical importance is whether the number of salmon reaching the fishery can be increased by reducing the fresh-water loss. It is by no means a foregone conclusion that a fishery will be benefited by simply reducing the loss of eggs in the redds or the loss of fry from predation. Even though the numbers of salmon reaching the sea were greatly increased, it is entirely possible that the loss in the ocean might increase correspondingly and the numbers reaching the fishery and the spawning streams remain unaffected. Several workers have considered this possibility (e.g., Murphy and Shapovalov, 1951; Neave, 1953) and have concluded that the sea mortality is density-independent.

Supporting evidence is meager, but it seems logical to suppose that if ways were found to increase the number of seaward migrants the number of adults would be increased within certain limits. Proponents of salmon hatcheries have made this assumption, and apparently there is no conclusive evidence to prove them wrong. Proponents of natural propagation contend that the same end can be reached simply by permitting salmon to spawn in sufficient numbers in their natal streams. On the basis of this assumption, the California Department of Fish and Game closed the Fall Creek Hatchery on the Klamath River in 1948. The chinook salmon which had been killed and stripped of their eggs for many years were then allowed to spawn wherever they could in the tributaries and in the main river below the California-Oregon Power Company's dam just south of the California-Oregon line.

Unfortunately the dam, which had been built in 1913, cut off the greater part of the original chinook salmon spawning area within the main river. It is possible that very few salmon originally spawned in the main river below the dam site. When the run was permitted to spawn anywhere it could, a great number ascended Fall Creek, the stream into which most of them had probably been released from the hatchery. This stream, as will be pointed out later, is not a typical chinook salmon spawning tributary.

It could be described as a steelhead trout stream which chinook salmon had been forced to use for spawning.

Although Fall Creek was probably relatively unimportant for chinook salmon spawning before the dam was constructed, in several respects it is well suited for an investigation of spawning efficiency. Its flow is small and relatively free of uncontrollable floods. Therefore, in 1950 a study was begun to determine the relationships between selected numbers of spawning adults and the resulting production of offspring. The work was patterned in general after similar studies conducted in British Columbia.

DESCRIPTION OF FALL CREEK

Fall Creek is a relatively small tributary of the Klamath River. It is the first stream to enter the river below the California-Oregon Power Company (Copo) dam, and therefore the last tributary into which fish may go as they swim upriver from the ocean. The mouth of Fall Creek is approximately 185 river miles from the sea. Throughout most of the year Fall Creek is supplied by springs just over the state line in Oregon. However, during winter rains it may be considerably swollen by surface drainage.

From its source in Oregon, Fall Creek flows through a shallow bed across the recent lava plateau. Just within the California boundary the stream reaches the edge of the plateau and falls perpendicularly to the foot of the rim. From here it proceeds 1.15 miles to the Klamath. Over 25 years ago the power company diverted Fall Creek, at a point above the falls, into a small electric plant at the foot of the lava rim. Therefore, at present Fall Creek flows through the power plant, then about $\frac{1}{4}$ mile into the original stream channel. The important section of Fall Creek, insofar as the salmon are concerned, lies between the mouth and the power plant, a distance of 1.15 miles.

The gradient of the stream is relatively steep, 1:32. The average width is approximately 14 feet. The velocity is high except in a few spots and many rocks and boulders form a series of low falls and cascades. Throughout most of its length the stream is densely overhung by alders and oaks.

The entire aspect of the stream would appear to favor steelhead trout rather than chinook salmon spawning. At only a very few places do the gradient, depth, velocity, and size of gravel combine to form "typical" chinook salmon spawning areas. The spawning gravel is composed entirely of lava fragments, worn moderately smooth but very irregular in size, and the beds are shallow. It is entirely possible that the average depth to which salmon can dig redds is less than optimal. The loss of eggs and fry during floods may be relatively great for that reason.

From the physical data shown in Table 1, it is apparent that the characteristics of Fall Creek are not suitable for even small-sized chinook salmon. This fact should be kept in mind in evaluating data on the spawning efficiency.

TABLE 1.—Physical characteristics of Fall Creek

Elevation (feet).....	2,317-2,509
Length of stream (miles) ¹	1.15
Volume of flow (cubic feet per second).....	32-298
Average width (feet).....	14
Area of bottom (square feet).....	85,120
Area of spawning gravel (square feet) ²	18,800
Gradient.....	1:32
Velocity of flow (feet per second).....	4-5
Temperature of water in 1950-51 (°F.).....	45.6° (39°-52° F.)

¹ Mouth to powerhouse² Approximate

The atypical physiography of Fall Creek is more or less compensated by a relatively uniform flow of suitable quality water (Table 2).

NUMBERS OF CHINOOK SALMON SPAWNING IN FALL CREEK

It was planned to allow a relatively large number of fish into the stream the first year and then to reduce this figure each year until the number seemed by inspection to be about optimal for the spawning areas. Obviously it would be practically impossible to prescribe the optimal number on the basis of the total gravel available and the average square feet of area required by a pair of spawners. Such an arbitrary method would be especially inappropriate for Fall Creek, where the spawning areas are generally small and variable in size and depth of gravel, and in the depth, velocity, and turbulence of water. Only by trial and observation could the best number of fish for the usable areas be determined.

TABLE 2.—Volume of flow (cubic feet per second) during period of year when chinook salmon are in Fall Creek

Year	Stream flow			Diversion flow into counting trap		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
1950-51.....	42	32	142	3.6	2.9	5.5
1951-52.....	52	35	161	3.2	2.5	7.7
1952-53.....	68	40	298	3.2	2.5	5.8
1953-54.....	51	33	137	3.2	2.3	6.8

The count of spawners entering Fall Creek is made at a wooden rack with adjoining trap located about 180 feet above the confluence with the Klamath River (Fig. 1). The fish, stopped by the rack, swim through a V-shaped opening and into a holding tank, where they remain until the attendant counts them and releases them above the barrier. From here they continue upstream to choose a spawning bed.

In the fall of 1950, 750 pairs were counted into the spawning area above the weir. They crowded the favored spawning areas so much that considerable interference resulted. Consequently, in 1951 the total number

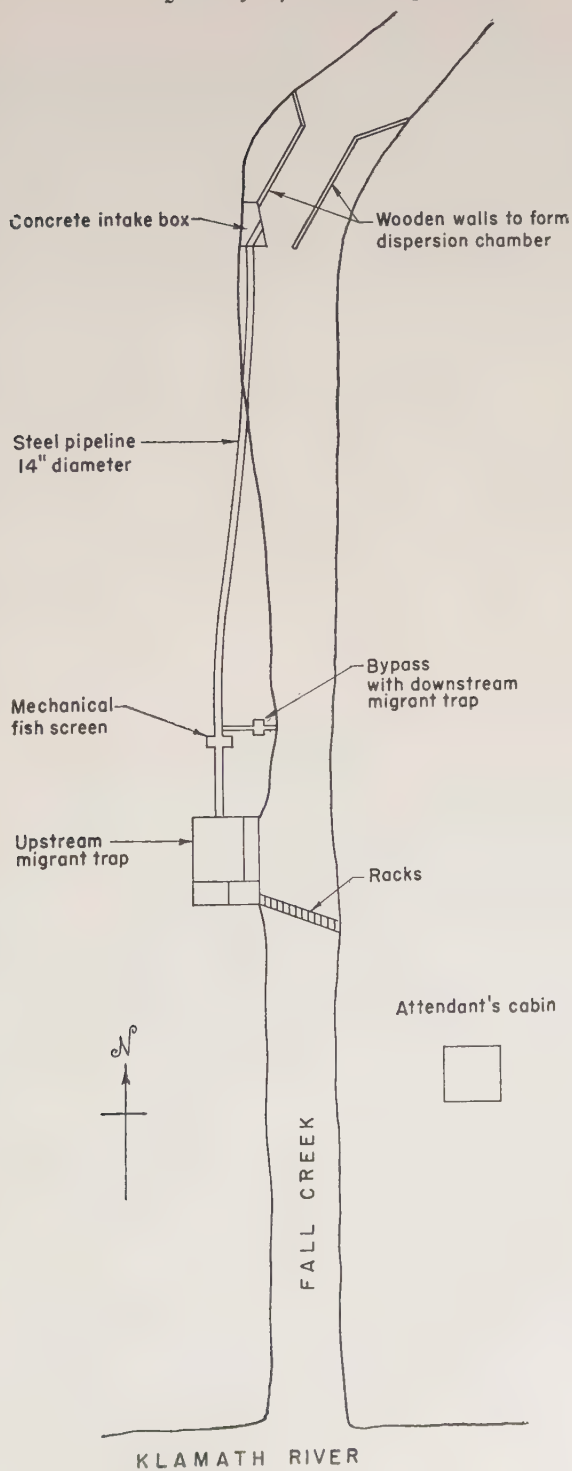


FIGURE 1.—Weir and trap in Fall Creek for counting the migrant, chinook salmon, spawners and also the structures for counting the downstream, migrant, chinook fingerlings in a fraction of the stream flow.

was reduced to 500 pairs. Inspection indicated that this number was still too large, so in 1952 only 300 pairs were permitted to enter. Since 300 pairs seemed to be closer to the proper figure, the same number was allowed to enter in 1953. The chronology of the planned escapement into the spawning area is given in Table 3.

Once a reasonably satisfactory release of fish was decided upon, it was planned to continue with this number for the duration of the investigation. Any variation in spawning success can thus be attributed to other factors. No intentional changes in the stream environment have been made as yet, but it seems probable that the importance of certain environmental factors, such as predator control, can be evaluated in this study.

In 1950 the total elapsed time from the date on which the first salmon entered Fall Creek until spawning ceased was 43 days; in 1953 it was 50 days. The entire stream from the counting station to the powerhouse after-bay was used except, of course, where the bottom is completely unsuitable.

TABLE 3.—*Adult chinook salmon (both sexes) counted into Fall Creek*

Date	1950	1951	1952	1953	Date	1950	1951	1952	1953
Sept. 9....	...	...	..	1	Oct. 1.....	28	52	36	31
do. 11....	...	...	..	1	do. 2.....	23	72	44	12
do. 13....	...	...	..	12	do. 3.....	39	120	68	..
do. 16....	...	...	..	7	do. 4.....	111	184	32	36
do. 17....	...	...	..	1	do. 5.....	38	94	35	75
do. 21....	...	...	..	5	do. 6.....	26	72	121	66
do. 22....	...	...	..	1	do. 7.....	16	15	..	61
do. 23....	...	...	3	3	do. 8.....	23	...	137	85
do. 24....	...	1	..	2	do. 9.....	41	36	18	88
do. 25....	...	34	3	..	do. 10.....	45	42	42	36
do. 26....	146	56	2	..	do. 11.....	...	12	..	29
do. 27....	170	59	14	2	do. 14.....	329	...	..	..
do. 28....	153	40	..	26	do. 15.....	171	...	..	..
do. 29....	94	53	21	6					
do. 30....	47	58	24	14	Total.....	1,500	1,000	600	600

Even in 1952 and 1953, when only 600 fish were released into the stream, the salmon did not distribute themselves evenly. It is presumed that several factors are important in the choice of redds and because all of these factors probably are not present in each spawning area it is not surprising that overcrowding occurs in some places, while other areas are little used. Briggs (1953) considered several factors which are important in the choice of redds.

In 1950 the spawners that were not permitted into Fall Creek were allowed to spawn as best they could in the rather unfavorable gravel of the Klamath River. In subsequent years they have been artificially stripped, their eggs taken to the Mt. Shasta Hatchery, and the resulting fingerlings returned to the Klamath River below the mouth of Fall Creek.

NUMBER OF EGGS DEPOSITED

The number of eggs in the female chinook salmon (Table 4) permitted to ascend above the counting station to spawn was estimated by deter-

mining the average member for 18–20 fish by the displacement method described by Burrows (1951). The average number arrived at by this means was used for the fish which spawned. An effort was made to spread the sampling throughout the run. Because of various practical considerations this was not always feasible. There is no reason, however, to suspect that the number of eggs per female varies through the season enough to require widely distributed samples with respect to time.

Heavy rains followed by marked increases in flow, velocity, and turbulence probably affect strongly the survival of eggs, fry, and fingerlings. It may be presumed that in each spawning stream there is a point beyond

TABLE 4.—Egg counts for Fall Creek chinook salmon and estimates of total numbers of eggs deposited in different years

Item	1950	1951	1952	1953
Number of females in sample.....	20	20	18	.....
Average fork length (inches).....	29.7	31.5	28.7	.....
Average weight (pounds).....	10.4	14.1	10.1	.....
Average number of eggs.....	3,423	3,948	3,888	.....
Total number deposited.....	2,567,000	1,974,000	1,166,000	1,166,000

¹ Egg counts were not made in 1953, so the average for the three preceding years was used

which the water flow cannot increase without harmful effect upon the eggs and alevins. This point is not known for Fall Creek, but is believed to have been exceeded several times during the study period. The presence of eggs and alevins in the downstream-migrant trap after peak floods, indicated that such flows were great enough to disturb the redds. Similar observations have been made at Nile Creek, B. C., where chum salmon redds were disturbed by floods (Neave, 1953). Figure 2 shows the stream flows each year during the period when chinook salmon were in Fall Creek. In the winter of 1952–53 the “floods” or peak flows were much greater than in the winter of 1953–54. In the following section it will be noted that the spawning efficiency of the 300 pairs of chinook salmon in 1952–53 was 9 percent, whereas in the following season it was 32 percent for the same number of fish. It is possible that lack of floods in 1953–54 was largely responsible for the greater spawning efficiency.

NUMBERS OF SEAWARD MIGRANTS

The number of downstream migrants was estimated by trapping a portion of the run and computing the total from it. Since this is a departure from the usual method, it will be described in some detail.

A wooden flume was built into the stream channel at a point about 300 feet above the mouth. This flume is 12 feet long, 10 feet wide and 2 feet high. At this point the stream has such a steep gradient that the water rushes through the flume faster than the swimming speed of the fingerlings. Just above the flume is a cascade which tends to mix the fingerlings in the water and prevent stratification. Into one side of the

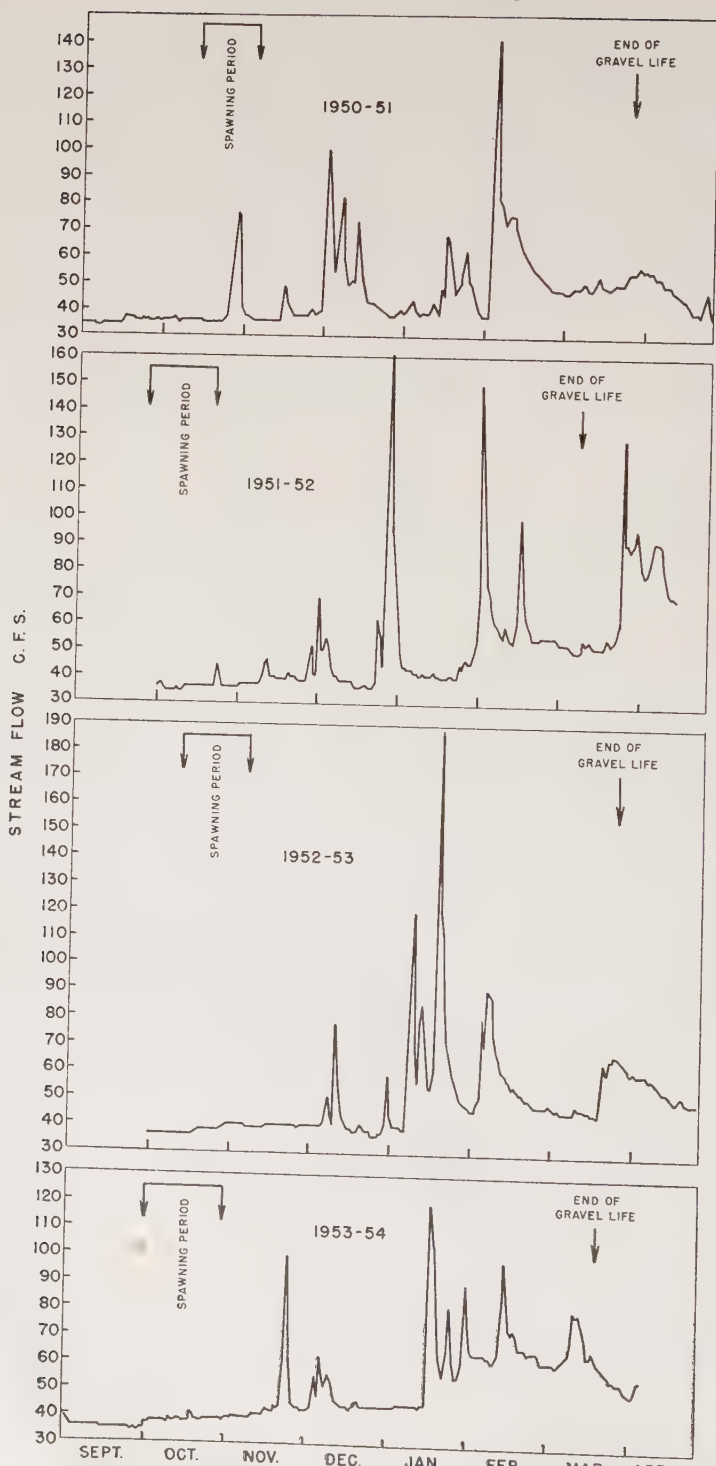


FIGURE 2.—Stream flows in Fall Creek, 1950-51 through 1953-54.

flume is built the opening of the 16-inch diversion pipe. As the water and fish rush down the flume a fraction is diverted into the pipe and carried 108 feet to the trap which is set on the bank of the stream. The trap is essentially a perforated-plate fish screen of the type used in California to exclude salmonids from smaller irrigation ditches (Wales, Murphey, and Handley, 1950 and Leitritz, 1952).

The small fish swim about in the concrete box above the screen until they find the "bypass" opening near the surface on the stream side of the screen. As the fish pass through the bypass they drop into a trap-box, where they can rest in quiet water until the attendant removes the wooden cover and dips them out for counting.

This trapping device has proved highly satisfactory. The screen surface is large (4 feet by 8 feet), while the volume of water passing through it is relatively small (2.3 to 7.7 cubic feet per second). The perforated plate is perfectly sealed along its margins, and the 5/32-inch diameter holes are too small for any chinook salmon fingerlings to pass through. The velocity and turbulence are so low that there is no tendency for the fish to be drawn to and held against the screen. Accurate gaging of the stream and diversion flows is essential to the Fall Creek system of counting downstream migrants. Fortunately, a U. S. Geological Survey stream gaging station is located above the diversion point. By use of a recording flow meter and a staff gage the entire flow of Fall Creek can be obtained at any time. Readings were taken from the staff gage twice a day by the attendant. Below the fish screen in the diversion was constructed a standard, rectangular stream-flow weir from which readings were taken twice a day. The entire system of diversion and trapping is almost completely self-operating and has proved highly satisfactory.

Although Fall Creek is relatively free from uncontrollable floods, it does have sudden fluctuations which have had some effect upon the counts of migrants. During the first 4 years of this investigation there were no floods which prevented an accurate count of the upstream migration of spawners, but in each year except 1953-54 there were peaks in flow which may have caused small errors in the downstream-migrant counts. During these peak flows it may be presumed that the ratio of water diverted into the counting trap to the flow in the stream may have changed without being detected.

From all indications the assumption that the concentrations of fish are the same in the diverted water as in the stream itself is justified. Lots of a few hundred fingerlings were accumulated in the trap and then given a temporary mark by removal of a caudal fin lobe. These young were carried upstream and liberated at a point just above the flume where the stream swept through a narrow cascade. Most of those which were captured in the trap entered within a day. Chi-square tests of the results of these experiments (Table 5) furnish evidence that the marked fish were well distributed throughout a cross section of the stream at the diversion intake. The chi-square values ranged from 0.009 to 1.839 and were well below the significant level. Even though the accuracy of this

TABLE 5.—*Tests of the validity of the proportional-diversion method of counting migrants*
 [Stream flows in cubic feet per second]

Date	Number marked	Number recovered	Percentage recovered	Fall Creek flow	Diversion flow	Percentage diverted	Number of fish expected	Chi-square	Approximate probability
1950									
March 6-8.....	400	21	5.2	54.5	2.9	5.4	21.6	0.018	0.90
do. 8-10.....	300	15	5.0	56.7	3.2	5.6	16.8	0.203	0.66
do. 13.....	200	9	4.5	47.6	2.5	5.0	10.0	0.105	0.75
do. 27.....	400	26	6.5	58.0	3.4	5.8	23.2	0.360	0.56
1951									
March 6.....	415	22	5.3	52.8	3.1	5.8	24.1	0.194	0.67
do. 12.....	561	25	4.4	55.5	3.2	5.8	32.5	1.839	0.18
1952									
March 21.....	500	28	5.6	54.0	3.0	5.5	27.5	0.009	0.93
1953									
February 10.....	350	11	3.2	74.0	3.2	4.4	15.4	1.316	0.26
do. 16.....	350	18	5.1	57.0	3.0	5.3	18.6	0.020	0.89
March 9-11.....	300	16	5.3	50.7	2.8	5.5	16.5	0.016	0.90
1954									
February 5-6.....	336	15	4.5	63.0	3.0	4.8	16.1	0.078	0.78
do. 22-23.....	300	15	5.0	64.3	3.3	5.1	15.3	0.006	0.94
March 2-3.....	322	19	5.9	61.0	3.0	5.0	16.1	0.550	0.46

method may not be as great as that in which all the migrants are trapped, it provides a relatively simple, inexpensive procedure for comparing the numbers of migrants from year to year.

Many of the migrants reaching the trap had not yet lost their yolk sac, and were therefore classed as fry. However, the majority were fingerlings in fork length from 1.1 to 2.3 inches (Table 6). Obviously, some of these fingerlings had been in the stream only a few days. The period when the fry and fingerlings are subject to predation is short. The first fry were trapped each year about January 1 and the last about April 1, 3 months later, the length of time any one migrant is subject to predation in the stream is probably only a few days. Tests made with a few fingerlings

TABLE 6.—*Seaward migration of fingerling chinook salmon from Fall Creek*

Item	1950-51	1951-52	1952-53	1953-54
Migration period.....	Dec. 27-Apr. 4	Dec. 24-Apr. 8	Jan. 5-Apr. 3	Dec. 31-Mar. 25
Number of migrants trapped....	10,419	9,774	5,550	16,950
Computed number of migrants....	175,000	196,000	102,000	358,000
Percentage of eggs which resulted in downstream migrants.....	7	10	9	32

given a temporary mark demonstrated that most of them required about 24 hours to descend 1 mile; the last was recovered 72 hours after liberation.

Few fish-eating birds are on the stream during the time of downstream movement. Mergansers are present on the Klamath River but appear not to feed in Fall Creek. An occasional California heron, belted kingfisher, and water ouzel can be seen along the stream, but no concentrations of bird predators have been observed. On the other hand, immature steelhead trout are abundant. Most of these trout are yearlings, but a few 2-year-olds also have remained. On February 15, 1951, 96 young steelhead trout were recovered in a representative stream section that was fished with a shocker. These fish ranged in length from 2.2 to 9.8 inches, and averaged 4.8 inches, fork length. Since the chinook salmon fingerlings averaged 1.3 inches at this time most of the steelhead were large enough to eat them. Twelve chinook salmon fingerlings and 28 steelhead eggs were found in their stomachs. Apparently very few coho salmon remain in Fall Creek long enough to feed on the chinook salmon fingerlings. Sculpins, *Cottus klamathensis*, are present, but they appear to be less abundant than in many streams. Immature steelhead trout are believed to be the most serious predators, followed by sculpins. Probably other predators are of minor importance.

SPAWNING EFFICIENCY

The term spawning efficiency has been used by British Columbia workers for the effectiveness of spawning of any particular run of fish. It is expressed as the percentage of the total number of eggs contained in

all of the females of the run which hatch, emerge, and finally migrate seaward past a counting station. When used with due respect for its limitations this measure is most valuable, particularly in comparing one season's run with another. The usefulness is greatly reduced when runs in different streams are being compared, because the counts are made at different points with respect to time and distance from the redds.

It can be seen from Table 6 that the spawning efficiency in Fall Creek in each of the 4 years varied considerably. The causes of these differences are unknown at this time. As is true with similar biological problems in which there are several variable factors, the tests must be repeated enough times to show the limits of variations under one set of experimental conditions. Since the four tests which have been made are little more than an exploration, no definite causes can be assigned.

Figure 2 shows that during incubation in 1953-54 there were fewer periods of high water than in the 1952-53 winter. It seems entirely possible that this steadiness of flow could be the cause of the higher coefficient of spawning efficiency. Again, we must point out that other factors could have been operative, although no other factors of any possible importance are known to have varied.

ACKNOWLEDGMENTS

The authors wish to express their thanks to Mr. Alan C. Taft, formerly Chief of the Bureau of Fish Conservation of the California Department of Fish and Game, under whose direction this study was begun. The help of Messrs. Harry Shott, Philo F. Jewett, Charles C. Cuddigan, and Richard Haley of the California Department of Fish and Game is also gratefully acknowledged.

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LIPIDS IN THE NORTHERN PIKE

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ABSTRACT

The northern pike, *Esox lucius*, is a ready source of food in many arctic and subarctic areas of North America. Because little information is available concerning lipids in fresh-water fish a study was made of these substances in the northern pike. Specimens were caught on hooks in Lake Minchumina, Alaska. Blood and liver were analyzed for fatty acids, sterols, and phospholipids. The pike is distinctive in having a rather high liver cholesterol—0.89 percent of fresh tissue. The other lipids are not unique but fall into the pattern for animals previously studied. However, marine fish in general have consistently more fat in the liver than does the northern pike.

INTRODUCTION

The livers of many fishes, especially those from arctic waters, are known to be extremely oily and to have a rather large total fat content. In the liver of stickleback, *Pungitius pungitius*, there is more cholesterol and more fatty acids than in the liver of the guppy, *Lebistes reticulatus* (Wilber and Del Pomo, 1949). Tissue lipids from various temperate-zone fishes have been assayed. The results vary as follows (all values as percentage wet weight of tissue): liver cholesterol—*Trutta fluviatilis* 0.68, *Gadus merlangus* 0.54, *Solea vulgaris* 0.47, plaice liver fatty acids 8.86, carp liver lipid phosphorus 0.099 (Weill, 1914; Mottram, 1912; Javillier, Cremieu and Hinglais, 1928).

The northern pike is widespread throughout Alaska. It is a ready source of food and is apparently well adjusted to its environment. Consequently, it seemed worthwhile to ascertain what lipids are present in the liver of this fresh-water fish and in what concentrations they occur. Also, it was felt that the blood lipid levels of the same species might throw some light on lipid turnover in northern fish.

MATERIALS AND METHODS

All specimens of the northern pike were collected from Lake Minchumina, Alaska by bait casting during the summer of 1950. Blood was quickly withdrawn (with a hypodermic needle) from the ventricle of six fish and immediately after landing put into a glass vial containing oxalate and fluoride. Upon return to the laboratory, measured volumes of the

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preserved whole blood were put into Bloor's mixture (ethanol and ether in a 3:1 ratio). In this condition the samples were flown back to St. Louis University where chemical analysis was made for total fatty acids, sterols, and phospholipids.

Pieces of liver, weighing 1 to 8 grams from 12 different specimens were stored in Bloor's mixture in sealed glass jars. These specimens were analyzed for the previously named lipids at St. Louis University.

The northern pike is a voracious feeder. The specimens taken for this work had been feeding on a small unidentified fish, resembling the lake cisco, *Leucichthys artedii* and locally called "smelt." Lake Minchumina was, at the time, "in bloom" and the water was extremely turbid with fine green algae.

All analytical methods were colorimetric. A Coleman Model 6A spectrophotometer was used throughout the work. Sterols were estimated by the Lieberman-Burchard reaction. Total fatty acids were measured by oxidation in Nicloux reagent and measurement of the resulting color change of the reagent. Phospholipids were estimated by oxidizing in Nicloux reagent after separation from other lipids with cold acetone and magnesium chloride. The resulting color change was measured in a spectrophotometer. Details of these methods are given by Wilber and Musacchia (1950).

BLOOD AND LIVER LIPIDS IN NORTHERN PIKE

Mean values for blood lipids of northern pike in milligrams per 100 milliliters (Table 1) were: total fatty acids, 771; sterols, 183; phospholipids, 411.

TABLE 1.—*Lipids in the blood of northern pike*
[Values in milligrams per 100 milliliters of whole blood]

Specimen	Total fatty acids	Sterols	Phospholipids
1.....	1,200	190	500
2.....	750	185	450
3.....	520	105	350
4.....	866	203	333
5.....	625	210	425
6.....	666	206	...
Mean.....	771	183	412

Mean values for the liver lipids as percentage of fresh tissue (Table 2) were: total fatty acids, 9.1; sterols, 0.89; phospholipids, 3.1. Other sterols may be included in the cholesterol since the analytical method used estimates all sterols.

BLOOD AND LIVER LIPIDS IN OTHER ANIMALS

Previous work indicates that cholesterol is the principal sterol found in fish oils (Jacobs, 1944). The principal phospholipid is said to be lecithin.

TABLE 2.—*Lipids in the liver of northern pike*
[Values as percentage of fresh tissue]

Specimen	Total fatty acids	Sterols	Phospholipids	Specimen	Total fatty acids	Sterols	Phospholipids
1.....	8.3	0.66	4.8	8.....	8.5	0.95	2.2
2.....	8.0	1.02	2.5	9..... ¹	 ¹	1.37	2.3
3.....	10.9	1.42	3.8	10.....	6.3	0.60	2.1
4.....	7.4	1.00	3.6	11.....	7.6	0.57	2.8
5..... ¹	 ¹	0.50	1.8	12.....	11.5	0.62	2.6
6.....	14.4	1.26	5.2				
7.....	7.7	0.80	3.0	Mean.....	9.1	0.89	3.1

¹ Determination not made

Ordinarily, triglycerides make up at least 95 percent of fish fats. "The fatty acid components consist of straight chain even-numbered 14 to 24 carbon acids with the carboxyl group at one end. The degree of unsaturation of the fatty acids increases with the number of carbon atoms. This degree of unsaturation is usually not greater than —4H for acids up to 18 carbon atoms but may be as high as —10H or more for C₂₀, C₂₂, and C₂₄ acids", (Jacobs, 1944).

Table 3 shows that fish livers contain amazingly large amounts of fat but that individual and species variations are appreciable. Since most available data deal with marine fish, these data for the northern pike contribute to our knowledge of the comparative biochemistry of fish.

TABLE 3.—*Oil content of the livers from various fish*¹

Species	Region taken	Percentage oil
<i>Theragra chalcogramma</i>	Alaska	30
<i>Raja stellulata</i>	Alaska	10—30
<i>Myoxocephalus</i> sp.	Alaska	5—20
<i>Gadus callarias</i>	Atlantic	40—60
<i>Sebastes ruberrimus</i>	Pacific	5—10
<i>Salmo gairdneri</i>	Pacific	10—20
<i>Squalus acanthias</i>	Atlantic	40—60
<i>Cynoscion mobilis</i>	California	15—30
<i>Pneumatophorus diego</i>	California	4—25
<i>Esox lucius</i>	Alaska	9

¹ Data for fish other than northern pike from Jacobs (1944)

The mean value of 771 milligrams total fatty acids per 100 milliliters of whole blood is not particularly high (Table 1). Similarly, blood cholesterol of northern pike falls well within the range of values usually found in carnivorous animals. Phospholipids in pike are high in comparison with the pig, rabbit, or man (Bloor, 1943). Phospholipid values found for northern pike fall within the range of published values for other poikilotherms: eel serum, 883 milligrams per 100 milliliters; turtle whole blood, 475 milligrams per 100 milliliters (Bloor, 1943; Wilber and Lieb, 1950).

Why many cold-blooded forms have blood phospholipid values which are constantly higher than those in many homoiotherms is not clear. The higher values found in the present work may be associated with a high rate of fat absorption and transport: the pike were feeding voraciously. Injury resulting from the hook might also be involved. In Table 4, blood lipid values for various animals are compared with those for pike.

Liver is known to be the primary organ for fat turnover (Bloor, 1943). Consequently, the variation in liver lipids reflect the level of fat turnover

TABLE 4.—*Mean blood lipid values for various animals*

[Values in milligrams per 100 milliliters of whole blood]

Animal	Fatty acids	Sterols	Phospholipids
Northern pike.....	771	183	412
Conger eel ²	1,957	163	883
Painted turtle.....	889	201	475
Harbor seal.....	956	175	729

¹ Data for animals other than northern pike from Bloor (1943)

² Values are for serum

going on at a given time. A comparison of Tables 2 and 3 immediately shows that there is appreciably less fat in the liver of the northern pike than in that of various marine fishes. Qualitative differences in food supplies are presumably of more importance than quantitative differences, since the "smelt" in Lake Minchumina furnishes abundant food for pike.

The mean phospholipid value of 3 percent in the pike liver does not suggest an appreciable rate of fat turnover. It is a value close to that found for livers of many poikilotherms (Table 5), and of some homoiotherms.

TABLE 5.—*Mean liver lipid values for various animals*

[Values as percentage of fresh tissue]

Animal	Fatty Acids	Sterols	Phospholipids
Pike.....	9.1	0.89	13.1
Frog.....	...	...	13.1
Carp.....	...	...	12.5
Seal.....	5.1	0.44	27.9
Polar bear.....	9.8	0.38	22.8
Walrus.....	4.2	0.26	23.6

¹ Bloor, 1943

² Wilber, 1954

The high percentage of sterols in pike livers in comparison with other animals indicates a need for complete fractionation of the sterol complex. Vitamin content of the liver should also receive careful consideration.

ACKNOWLEDGMENTS

A small grant from the Arctic Institute of North America helped to support this work. The cooperation of the Military Air Transport Service in providing transportation to and from Alaska is appreciated. Colonel Jack Bollerud, former Commanding Officer of the USAF Arctic Aeromedical Laboratory, was especially helpful in aiding completion of the field work.

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SULFONAMIDE TOXICITY IN BROOK TROUT

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ABSTRACT

Sterility was observed in female brook trout that were treated with sulfamerazine at frequent intervals for 2 years to control endemic furunculosis. Feeding sulfamerazine for a period of 8 months caused massive kidney damage similar to that observed in humans who develop allergies to "sulfa" drugs. Kidney damage of the type observed would probably cause renal insufficiency which would handicap any physiological function including reproduction. Feeding sulfonamides for periods up to 13 weeks did not produce kidney damage.

INTRODUCTION

Sulfonamide toxicity has been recognized and documented frequently in the therapy of humans and domestic animals. With the increasing use of these drugs for the control of fish diseases various workers have cautioned that indiscriminate feeding would be harmful. Gutsell and Snieszko (1949) noted a decreased growth rate on diets containing sulfamerazine. This effect was most apparent with brown trout (*Salmo trutta*). Snieszko (1952) observed that the long-range prophylactic use of antibiotics might result in drug-resistant strains of pathogens and would also be toxic to the treated fish. Heavy mortality of coho salmon fingerlings (*Oncorhynchus kisutch*) after treatment with sulfamerazine was reported by Johnson and Brice (1953). The effect on growth of three species of trout by several sulfonamides has been described by Snieszko and Wood (1955).

Among the most common undesirable reactions in humans are those due to hypersensitivity and allergy which may be manifested in many different forms, all rather non-specific and difficult to diagnose. Kidney damage may result from allergic reactions or from the mechanical obstruction of precipitated sulfonamide crystals which may lead to symptoms of renal insufficiency. In fish, poor growth due to sulfonamides has

¹ P.O., Kearneysville, West Virginia

generally been attributed to reduced consumption of food and the causes of mortality have not been determined.

An unusual case which very likely resulted from sulfa toxicity was reported by a Maryland State Fish Hatchery in January 1953. To control endemic furunculosis in young brood stock of brook trout (*Salvelinus fontinalis*), sulfamerazine had been fed prophylactically for several days every month for 2 years. As the first spawning season approached the fish appeared to be maturing normally. The females became enlarged and felt "ripe" to experienced spawntakers. No eggs were obtained, however, and when it became evident that the eggs were being resorbed, the fish were taken to the Fish and Wildlife Service Experimental Station at Leetown, West Virginia, for examination.

A gross examination revealed no abnormal pathology. The ovaries and testes were in a normal stage of retrogression. Eggs were being resorbed in all females examined as would be expected in mid-January if spawning had not occurred the previous fall. The advanced stage of this process made it impossible to determine whether the eggs had reached full maturation before resorption began. All other organs were apparently normal. Histological examination, however, revealed massive kidney damage somewhat similar to the lesions observed in mammals after excessive "sulfa" therapy. These observations prompted an experimental program to determine under what conditions tissue damage could be caused in trout by over-medication with sulfa drugs.

METHODS

Experiment 1.—On June 24, 1953, sulfamerazine treatments were started on two lots of fingerling brook trout. In both lots the fish were fed 8 grams of sulfamerazine per 100 pounds of trout per day (about 175 milligrams per kilogram trout). Lot No. 1 was fed the drug on Mondays and Tuesdays of each week. Lot No. 2 was treated for 1 full week (the first week) each month. Each group was given approximately the same total amount of sulfamerazine during the experiment. The only variable between the two lots was the frequency of medication. Samples were removed for histological examination after 16, 26, and 34 weeks of medication. The total course of the experiment was approximately 8 months.

Experiment 2.—On April 12, 1954, duplicate lots of fingerling brook trout, brown trout, and rainbow trout (*Salmo gairdneri*) were started on diets containing the following drugs: sulfamerazine, sulfisoxazole (Gantrisin), sulfamerazine (6 parts) and sulfaguanidine (4 parts). All sulfonamides were given at a rate of 9 grams per 100 pounds of trout per day (200 milligrams per kilogram of trout). Duplicate controls were fed the same diets without sulfa drugs. The brook trout and rainbow trout were maintained on this experiment for 8 weeks; the brown trout were continued for an additional 5 weeks. This experiment was designed to test the effect of sulfonamides over a relatively short period of time. The

dosage was only slightly higher, but the amount of drug given per month was about five times greater than that used in Experiment 1.

Tissues were fixed in Bouin's solution for 24 hours and stored in 65-percent alcohol. Paraffin sections were stained with hematoxylin and eosin, and by the Dunn-Thompson and Okajima methods for hemoglobin (Lillie, 1948). Sulfonamide-specific stains were not used due to difficulties of proper fixation and a lack of freeze-drying equipment.

EFFECTS OF SULFONAMIDES

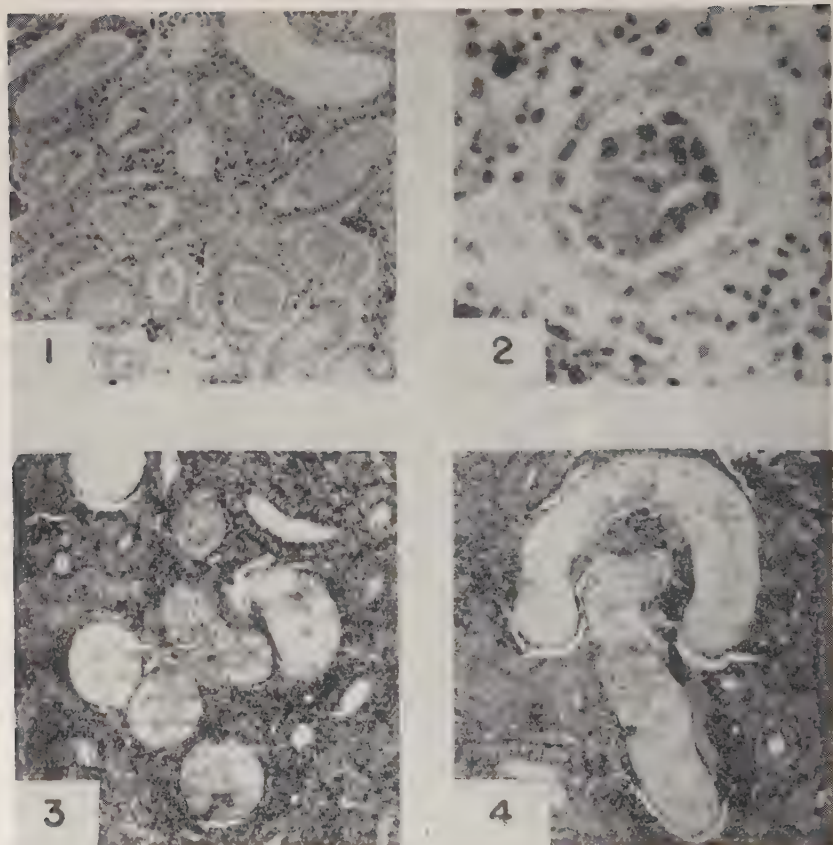
A striking feature of the kidney lesions observed in the Maryland trout, which had been fed sulfamerazine prophylactically for 2 years, was an extensive tubular degeneration (Figs. 3 and 4). In hematoxylin and eosin sections these tubules appeared as opaque, necrotic, white or light-yellow structures with all cellular detail obscured. The degeneration began in the proximal parts of the convoluted tubules and extended to the distal portions where it appeared to be in a more advanced stage. Combined with these lesions were large numbers of small globular masses scattered throughout the hematopoietic tissue (Figs. 7 and 8). These masses stained bright red with eosin and were acellular. When hemoglobin-specific stains were used, both the globular masses and degenerate tubules stained hemoglobin-positive. The globular masses appeared to be entirely hemoglobin, whereas the degenerate tubules seemed to be completely impregnated with the blood pigment. In less advanced cases, entire erythrocytes were occasionally seen in the tubule lumens. No sulfonamide crystals were observed.

Experiment 1.—The sample taken after approximately 16 weeks of sulfa medication did not show pathology related to the experimental therapy. After 26 and 34 weeks, the brook trout exhibited pathology similar to that observed in the Maryland fish, although the lesions appeared to be earlier forms or less severe. Well defined casts and degeneration of tubular epithelium were observed in both samples (Figs. 1 and 2). However, discrete masses of hemoglobin were observed in the hematopoietic tissue in the last collection only (Figs. 5 and 6). Tubules permeated with hemoglobin were not observed in any of the experimental fish. Sulfonamide crystals were not observed. The incidence of kidney lesions was slightly greater in the group fed sulfamerazine twice daily.

Experiment 2.—No pathological condition was observed in any experimental group that could be correlated with sulfonamide toxicity.

DANGER OF CONTINUED HIGH-LEVEL TREATMENT

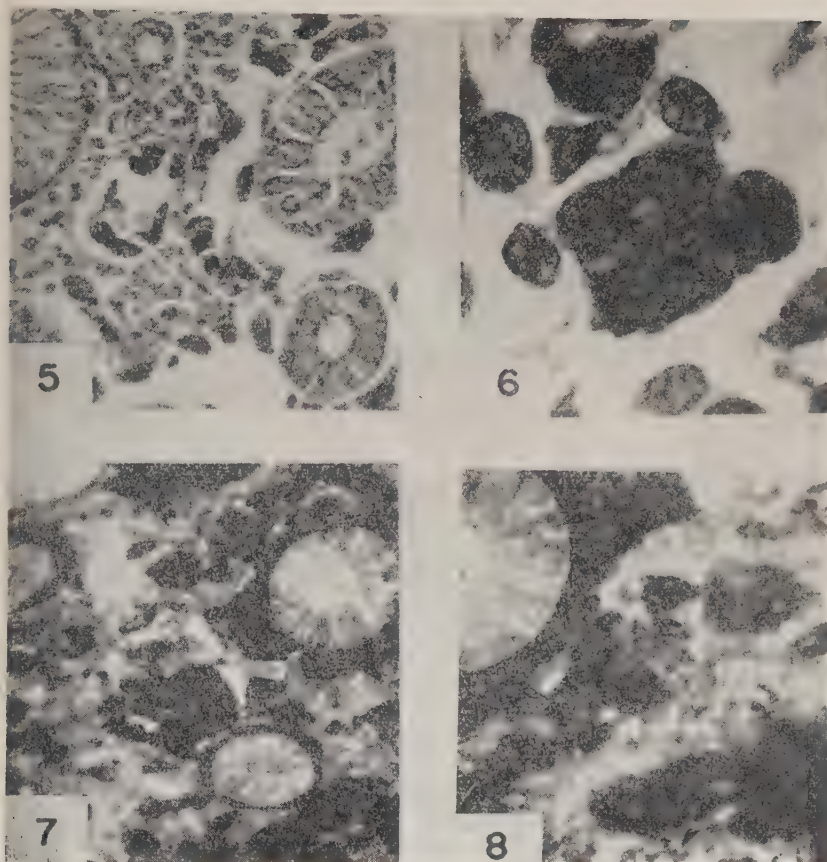
The kidney lesions in humans and domestic mammals caused by sulfonamide toxicity bear some resemblance to those observed in fish that have been fed excessive amounts of sulfa drugs. The renal reaction to the sulfonamides that is of most concern to humans, both because of its frequency and its gravity, is hemoglobinuric nephrosis (Allen, 1951). This condition is characterized by casts of hemoglobin or related pigment



FIGURES 1-4. Kidney lesions in brook trout. 1. Casts in tubules and tubule degeneration after 26 weeks of sulfamerazine medication. Experiment 1. Hematoxylin and eosin $\times 100$. 2. Degenerating erythrocytes in tubule. Experiment 1. Hematoxylin and eosin $\times 400$. 3 and 4. Tubules permeated with hemoglobin after 2 years of medication. Maryland fish, Okajima stain $\times 200$.

globins in the distal convoluted or collecting tubules. The massive deposits of hemoglobin seen in both the hematopoietic and renal tissues of fish are not morphologically similar to the casts of hemoglobinuric nephroses; thus the etiology of the lesion is possibly not the same as that observed in mammals. It appears likely, however, that the lesions in fish are associated with allergic reactions, as are similar lesions in mammals. The absence of sulfonamide crystals may be due to the histologic processing since the crystals are water-soluble.

Tissue damage in fish is apparently caused by sulfonamides, but only after remarkably long periods of medication at relatively high dosages.



FIGURES 5-8.—Kidney lesions in brook trout. 5. Hemoglobin in hematopoietic tissue of kidney after 34 weeks of medication. Experiment 1. Okajima stain $\times 200$. 6. Same as Fig. 5 $\times 400$. 7. Hemoglobin in hematopoietic tissue after 2 years of medication. Maryland fish. Okajima stain $\times 200$. 8. Same as Fig. 7 $\times 400$.

The feeding level of sulfamerazine in Experiment 2 was approximately twice the normal dosage prescribed for humans, but apparently the period of medication was too short to develop kidney lesions. The tolerance to such high levels might be explained by poor intestinal absorption, but Snieszko and Friddle (1951) have shown that high tissue levels do result. They observed blood concentrations as high as 25.0 milligrams percent following 9 days of medication at the rate of 200 milligrams of sulfamerazine per kilogram of trout. In human patients, blood levels of 10 to 15 milligrams percent are induced only when the danger from disease outweighs the increased danger of toxic effects.

Despite the relatively high resistance of trout to sulfonamide toxicity, it has been demonstrated that prolonged usage will damage the kidney. The evidence from the Maryland fish that over-medication will cause sterility has not been confirmed experimentally. However, kidney damage of the degree observed in the Maryland fish would undoubtedly result in renal insufficiency severe enough to place a systemic handicap on any physiological function. That normal reproduction would be affected adversely as a secondary effect is entirely possible.

It appears that the continued use of sulfa drugs at low levels over long periods is more harmful than high levels for short periods. The results obtained experimentally by feeding sulfamerazine at two frequencies for long periods were not sufficiently different to permit a recommendation based on either frequency. Both methods of feeding led to kidney damage.

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THE PYGMY WHITEFISH, *COREGONUS COULTERI*, IN LAKE SUPERIOR

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ABSTRACT

Bottom trawling by the U. S. Fish and Wildlife Service motor vessel *Cisco* in Lake Superior in 1952-1953 revealed a large population of a tiny whitefish, *Coregonus (Prosopium) couleri*, which has been reported previously only from northwestern North America. The hiatus in range, from Lake Superior to the

Columbia River basin, is the greatest known for a North American freshwater fish. Although minor structural differences characterize the disjunct populations of the pygmy whitefish, these are not deemed worthy of nomenclatorial recognition. Comparisons with related species indicate that the pygmy whitefish is distinctive in the small size, large scales, few vertebrae, few pyloric caeca, and in other characters.

The pygmy whitefish is widely distributed in Lake Superior, especially in semi-protected bays, such as Keweenaw Bay which yielded about 68 percent of the 1,623 specimens caught. The bathymetric range was 10 to 49 fathoms, with maximum abundance at the 25- to 39-fathom interval. Average length of fish increased progressively with water depth, chiefly because the number of yearlings declined from 100 percent at 10-14 fathoms to none at 45-49 fathoms.

The average total length of pygmy whitefish caught by trawling was 3.4 inches (range 1.2 to 5.7). Extraordinarily slow growth was revealed by the examination of scales. Two fish from Keweenaw Bay, both nearing the end of their eighth growing season, were only 5.4 inches long. Compared to Keweenaw Bay, growth rate was about the same near Laughing Fish Point, faster in the Apostle Islands (and in Bull and McDonald Lakes, Montana), and slower in Siskiwit Bay, Isle Royale. Females grew more rapidly than males after the second year and had a longer life span.

All male pygmy whitefish were mature at the age of 2 years and a total length of 3.6 or more inches. Most females were mature at 3 years and 4.2 inches; all older females were mature. Mean egg production was 362 (range, 93 to 597) per fish and 26 per gram of total weight for fish from 3.4 to 5.9 inches long. Spawning in 1953 occurred sometime in November or December.

Crustacea (principally ostracods and amphipods—copepods in the young) occurred in 106 of 112 pygmy whitefish stomachs and made up 77 percent of the total food volume. When available, fish eggs appear to be important in the diet.

Other cold-water fishes—cottids, ninespine sticklebacks, smelt, and four species of coregonines—were the most frequent associates of the pygmy whitefish. Lake trout and trout-perch were also taken with it at the same stations or in the same trawl hauls. Its closest relative in Lake Superior, the round whitefish, was not an ecological associate.

INTRODUCTION

One of the most comprehensive studies yet attempted on a sizable group of fishes over a considerable region, the monograph of the whitefishes of the Great Lakes (Koelz, 1929), presented a wealth of information on the taxonomy, morphometry, areal and bathymetric distribution, size, abundance, breeding habits, and variation of the 11 species known from the area. The possibility that any species was overlooked in this survey seemed remote. Yet the introduction of bottom trawling by the U. S. Fish and Wildlife Service motor vessel *Cisco* in 1952-1953 revealed an abundant population of a tiny whitefish, *Coregonus coulteri*, in Lake Superior. The small size accounts for the failure of earlier investigators to collect it, since this whitefish is not vulnerable to the commercial gill or impounding nets that are fished where it lives. The bathymetric distribution, from about 10 to 49 fathoms, accounts for the failure of the species to appear in shore collections taken with small-mesh gear.

The discovery of pygmy whitefish in Lake Superior is particularly fascinating because all previous records of occurrence are from the Pacific slope. The present new record reveals a gap of roughly 1,100 miles in the distri-

bution. No other freshwater or terrestrial vertebrate (birds excepted) in North America is known to us to display such a strikingly disjunct range. In reporting the discovery of the species in Lake Superior we have felt impelled to compare this stock carefully with that from the Pacific slope. In addition, we contrast it with its closest relative in the Great Lakes basin, the round whitefish, *Coregonus cylindraceus* (termed *Prosopium quadrilaterale* by Koelz), and present information on occurrence within the lake, bathymetric distribution, size, growth, reproduction, food, and associates.

MATERIALS AND METHODS

Pygmy whitefish were collected at 17 stations in Lake Superior (Table 1; Fig. 3) by dragging an otter trawl along the lake bottom. Most were caught in nets 35 feet wide at the wings and 36 feet long. Mesh sizes of the cotton netting ranged from $1\frac{1}{2}$ and $2\frac{1}{2}$ inches (extension measure) at the forward end to $\frac{1}{2}$ inch at the cod end. Ordinarily the trawl was lowered to the bottom, towed for 10 minutes (usually parallel to the contour), and then retrieved. Water depth over the area trawled was recorded by a fathometer, and station locations were determined by radar.¹ The distance covered in a 10-minute haul depended partly on prevailing winds and currents, but probably averaged about $\frac{1}{2}$ mile. Fish caught were preserved in formalin immediately after collection. All measurements and weights given in this paper were made after preservation.

Morphometric measurements and counts have mostly been taken as described by Koelz (1929, pp. 305–308). Head length, as measured, includes the opercular membrane. The upper-jaw length was measured from the tip of the snout, apparently in the same way as Koelz measured the "maxillary." An orbital diameter is employed to replace the eyeball measurement used by Koelz. All rudimentary gillrakers are included in the count. Lateral-line scales were counted to the base of the caudal fin, irrespective of the position of the last pored scale; this count is not exactly equivalent to Koelz' method. For fin-ray counts all elements in the pectoral and pelvic fins are included. The last ray of the dorsal and anal fins is counted as double at the base (as recorded also by Koelz), but all anterior elements are included, no matter how short; thus the counts are taken in the same manner as by Dymond (1943) but are two or three higher than Koelz' tabulations, in which the first ray approached three-fourths the length of the longest ray in the fin. Unbranched and branched rays are segregated, then summed (e.g., iii + 8 = 11). The number and lengths of the unbranched rays in these fins vary erratically, and enumeration of all rays provides the most stable, hence probably the most reliable, count.

In addition to the Lake Superior specimens we have examined the following material of *Coregonus coulteri*:

¹ A description of the *Cisco* and its navigational and research equipment was given by Moffett (1954).

TABLE 1. — *Collection localities for the pygmy whitefish in Lake Superior, 1952-1954*

[See Figure 3 for location of stations]

General locality	Station	Latitude	Longitude	Date	Depth (fathoms)	Time trawled (minutes)	Number of fish	Total length ¹ (millimeters)
Wisconsin North of Apostle Islands..... Apostle Islands..... Apostle Islands.....	1	47° 09' 15"	90° 30' 00"	Aug. 20, 1952	32-33	8	1	122
	2	47° 00' 30"	90° 47' 30"	July 28, 1953	6-16	47	2	72-126
	3	46° 54' 15"	90° 35' 30"	May 30, 1953	11-46	60	26	93-146
	4	46° 46' 50"	90° 49' 15"	July 29, 1953 ²	30-32	...	6	143-149
	5	46° 48' 40"	90° 38' 35"	July 30, 1953	22	10	1	116
Michigan Siskiwit Bay, Isle Royale.....	6	47° 54' 40"	88° 57' 00"	Sept. 7, 1953	14-38	52	108	32-108
	7	47° 12' 30"	88° 08' 00"	Sept. 30, 1953	13-18	20	266	35-91
	8	47° 05' 30"	88° 10' 00"	July 9, 1953	11-25	30	4	61-72
	9	47° 03' 00"	88° 20' 45"	May 7, 1953	31	6	7	88-136
	10	46° 59' 30"	88° 22' 00"	July 8, 1953	18-28	40	111	62-121
Western Keweenaw Bay..... Southern Keweenaw Bay.....	11	46° 48' 21"	88° 26' 55"	Sept. 5, 1953	10-17	29	2	31-72
	12	46° 53' 30"	88° 21' 35"	Oct. 3, 1953	15-23	30	22	70-85
	13	46° 58' 45"	88° 07' 30"	July 8, 1953	15	10	12	54-73
	14	47° 03' 00"	88° 04' 55"	May 11, 1953	39-50	129	4	104-123
	15	46° 34' 10"	87° 12' 50"	July 11, 1953	27-33	30	83	65-134
Eastern Keweenaw Bay..... Off Point Abbaye..... Northeast of Point Abbaye..... East of Marquette..... Laughing Fish Point.....	16	46° 31' 20"	86° 55' 30"	Aug. 2, 1953	10-42	120	188	62-134
	17	46° 56' 40"	84° 46' 25"	Sept. 11, 1953	13-43	114	345	61-141
	18	46° 53' 30"	88° 21' 35"	Oct. 2-3, 1953	14-32	43	71	67-133
	19	46° 58' 45"	88° 07' 30"	Oct. 15, 1953	14-45	135	252	59-140
	20	46° 53' 30"	88° 21' 35"	Oct. 15, 1953	10-18	65	9	65-74
Ontario North of Whitefish Bay.....	21	46° 56' 40"	84° 46' 25"	Sept. 10, 1953	10-17	35	6	31-80
	22	46° 58' 45"	88° 07' 30"	Aug. 16, 1952	34-55	9	20	90-140
	23	46° 34' 10"	87° 12' 50"	Aug. 12, 1953	42	6	1	126
	24	46° 31' 20"	86° 55' 30"	July 13, 1953	18-19	50	1	74
	25	46° 53' 30"	88° 21' 35"	July 22, 1953	16-18	35	1	64
	26	46° 58' 45"	88° 07' 30"	Aug. 12, 1953	11-22	42	2	61-63
	27	46° 56' 40"	84° 46' 25"	Sept. 14, 1953	13-39	120	34	33-109
	28	46° 53' 30"	88° 21' 35"	Oct. 5, 1953	15-30	50	19	40-84
	29	46° 58' 45"	88° 07' 30"	Oct. 21-22, 1953	13-40	103	10	47-124
	30	46° 53' 30"	88° 21' 35"	Jan. 11, 1954	43-54	40	5	94-127
	31	46° 56' 40"	84° 46' 25"	Aug. 19, 1953	27-28	20	3	84-90
	32	46° 53' 30"	88° 21' 35"	Sept. 7, 1953	14-38	52	108	32-108
	33	46° 58' 45"	88° 07' 30"	Sept. 30, 1953	13-18	20	266	35-91
	34	47° 12' 30"	88° 08' 00"	July 9, 1953	11-25	30	4	61-72
	35	47° 05' 30"	88° 10' 00"	May 7, 1953	31	6	7	88-136

¹ Range in length refers only to specimens which were preserved; 96 fish were discarded at the time of collection² Three tiny coregonines, 21 to 29 millimeters in total length that were caught by trawling on July 29 at 5 to 9 fathoms, about 10 miles northeast of Station 3, were probably pygmy whitefish. Since identity is not certain, however, they are not considered elsewhere in this paper³ Nylon gill nets, 1-inch mesh (extension measure)

UMMZ² 167,941, here designated as lectotype of *Coregonus coulterii* Eigenmann and Eigenmann, a tuberculate, adult male, 92.5 millimeters in standard length, collected in the Kicking Horse River, elevation 4,050 feet, Columbia River system, at Field, British Columbia, by Carl H. Eigenmann in 1892. (Data on the lectotype are given in Table 2.) This specimen together with four others, UMMZ 61,949, was formerly catalogued as Indiana University 4,446. Eigenmann's original collection consisted of over 100 syntypes. Others seen by us are USNM 44,875 (3 specimens) and USNM 64,089 (1). One specimen is now in the British Museum (Dymond, 1943, p. 203) and 7 are in the Stanford collection (Böhlke, 1953, p. 13). Although Evermann and Smith (1896, p. 290) and subsequent authors have specified USNM 44,875 as "type" of *C. coulterii*, this action does not constitute valid designation of a lectotype (Int. Comm. Zool. Nomen., 1953, pp. 72-77) since the lot referred to includes three specimens, as noted by Böhlke (1953).

USNM 126,910 (3), Lake Aleknagik, Alaska, August 2, 1911, G. Dallas Harma and July 20, 1909, M. C. Marsh.

SU 24,809 (1), Chignik River near weir, Alaska, June 11-19, 1928, Harlan B. Holmes.

SU 24,810 (3), Upper Chignik River, Alaska, June 7-8, 1928, H. B. Holmes.

SU 24,811 (12), Chignik River at coal mine, Alaska, August, 1924, Charles Petry. BC, 54-423 (2), Lower Arrow Lake, sandy point opposite Renata, British Columbia, June 26, 1949, T. G. Northcote.

SU 5,477 (2), Diamond Lake, Pend Oreille County, Washington, June, 1894, J. O. Snyder. Diamond Lake was said by Snyder (1917) to be located in Stevens County, Washington, a statement repeated by other workers. There is a Diamond Lake in Pend Oreille County, and Clarence F. Pautzke, Chief, Fishery Management Division, Washington Department of Game, confirms our suspicion that this must be the lake intended.

MSU W53-2 (5) and UMMZ 167,942 (5), mouth of Ross Creek, Bull Lake, tributary to Kootenai River, near Troy, Lincoln County, Montana, December 26, 1952, J. B. Dillon.

MSU W53-3 (7) and UMMZ 167,943 (6), same locality, January 12, 1953, Kenneth Hays.

USNM 104,688 (2) mouth of Fish Creek, Lake McDonald, Glacier National Park, Montana, August 25, 1935, L. P. Schultz and A. S. Hazzard.

USNM 101,606 (4), near mouth of McDonald Creek, Lake McDonald, Glacier National Park, Montana, probably late November 1935, C. L. Croghan.

USNM 102,375 (37), Lake McDonald, Glacier National Park, Montana, November 17, 1936, C. L. Croghan.

GENERIC PLACEMENT

European ichthyologists have long and consistently grouped the whitefishes other than *Stenodus leucichthys* in the single genus *Coregonus*. North American authors, in contrast, have for the most part adopted the segregation advocated by Koelz (1929) into three genera—*Leucichthys*, *Coregonus*, and *Prosopium*. Koelz keyed out the species (and genera) of whitefishes in each of the Great Lakes, defined the characters of each genus on the basis of the species present in that region, and evaluated the principal characters employed in whitefish taxonomy, again confining his critique to local species. Nowhere did he include extralimital forms in a clear definition of the genera. The differences between genera as stated may seem adequate, but each of two of the "genera" was represented by a single

² Abbreviations for museum specimens are as follows: BC, University of British Columbia; MSU, Montana State University; SU, Museum of Natural History, Stanford University; UMMZ, Museum of Zoology, University of Michigan; USNM, United States National Museum.

species then known in the Great Lakes fauna. How tenuous was the basis for the segregation of *Prosopium* may be illustrated by consideration of the characters of the pygmy whitefish. Koelz (1929) distinguished *Prosopium* (*quadrilaterale*) from the other whitefishes of Lake Superior in several characters. The pygmy whitefish agrees with *Prosopium*, as defined, in the single narial flap, the lack of vestigial teeth on the jaws and the roof of the mouth (although lingual teeth are present), the number of gillrakers, and the subterete body. *C. couleri* agrees with *Leucichthys* and *Coregonus* but differs from *Prosopium* in the size of the exposed field of the lateral-line scales (not conspicuously smaller than the adjacent rows); fits *Coregonus* better than *Prosopium* in shape of snout, size of upper jaw, length of mandible, ratio of pelvic length to pelvic-anal distance, and presence of nuptial tubercles on the head; and is intermediate between *Prosopium* and *Coregonus* in gillraker length. In our judgment the morphological basis for segregation of genera becomes untenable if extralimital species, which reduce even further the utility of the differentiating characters, are included. We, therefore, agree with the generic nomenclature of Berg, Järvi, Regan, Svärdsön, Thienemann, and other European investigators, and with those recent American and Canadian ichthyologists (e.g., Shapovalov and Dill, 1950; Legendre, 1954; Wilimovsky, 1954) who have of late employed *Coregonus* (*sensu lato*). Also, we follow Regan (1914) and Berg (1940) in assigning the whitefishes to a subfamily, Coregoninae, of the Salmonidae.

Coregonus (*Prosopium*) *couleri* EIGENMANN AND EIGENMANN—
PYGMY WHITEFISH

Coregonus couleri.—Eigenmann and Eigenmann [not E. and G.—a typographical error], 1892, pp. 961–963 (original description; Kicking Horse River, 4,050 feet, Field, British Columbia). Evermann and Smith, 1896, pp. 288, 290–291 (description and comparisons; pl. 12; Kicking Horse River, Field, B. C.). Jordan and Evermann, 1896–1900, pp. 462–463, pl. 76 (compiled). Halkett, 1913, p. 48 (compiled). Cockerell, 1913, pp. 125–126 (scales).

Coregonus couleri.—Eigenmann, 1894, pp. 105, 115, 119, 121, 132, pl. 6 (description; Kicking Horse River, Field and Golden, B. C.). Evermann and Goldsborough, 1907, p. 99 (compiled). Jordan and Snyder, 1909, p. 430 (comparisons; Diamond Lake [Pend Oreille Co.], Washington). Jordan and Evermann, 1911, p. 41, fig. (compiled). Kendall, 1917 (description; Second Lake and stream connecting it with First Lake, Chignik [Alaska Peninsula], Alaska). Snyder, 1917 (preyed upon by kingfishers; Diamond Lake, "Stevens Co.," Washington). Snyder, 1919, p. 4 (compiled). Kendall, 1921 (size [maximum total length 198 millimeters]; description; food; Lake Aleknagik, Alaska). Wilimovsky, 1954, p. 282 (range).

Prosopium couleri.—Jordan, Evermann, and Clark, 1930, p. 65 (compiled). Schultz, 1936, p. 139 (comparisons; range). Schultz, 1941, pp. 8, 24–25, 39, fig. (characters; Fish Creek and McDonald Creek, tributaries to Lake McDonald, Glacier National Park, Columbia River basin, Montana). Wynne-Edwards, 1952, p. 16 (Sockeye Lake on the upper Alsek, 60°30'N., 137°38'W., Yukon Territory; records compiled). Weisel and Dillon, 1954, pl. 1 (characters; natural history; Bull Lake, Lincoln Co., Montana).

Prosopium couleri.—Myers, 1932 (comparisons; Kicking Horse River, Field, British Columbia; Diamond Lake, Washington; Chignik River, Alaska).

Dymond, 1943, p. 202–203 (characters). Dymond, 1947, p. 8 (characters; records, including Yukon [Territory]). Carl and Clemens, 1948 (and 1953), p. 35, figs. (compiled).

Prosopium snyderi.—Myers, 1932 (original description; figure; holotype, SU 23,751, Crescent Lake, Olympic Peninsula, Washington). Schultz, 1936, p. 139 (comparisons; Lake Crescent, Olympic Peninsula, Washington). Myers, in Böhlke, 1953, p. 14 (“Crescent Lake may not have been the one on the Olympic Peninsula”).
Coulter's whitefish.—Wynne-Edwards, 1947, pp. 12, 19 (Sockeye Lake, Alsek River system, Yukon Territory).

NOMENCLATURE

The original specific name *coulterii* is emended to *coulteri* in accordance with the recent decisions on patronymics established by the International Commission on Zoological Nomenclature (1953).

As indicated in the above synonymy, the type locality of *Prosopium snyderi* Myers cannot now be located with certainty. It is clear from the original account that this nominal species is close to *C. coulteri*. *P. snyderi* was said to differ from *coulteri* principally in certain body proportions, notably the longer fins, and in the larger scales. The lateral-line scale count, however, is well within the limits of variation for *coulteri*, as are most of the proportional measurements (Table 2). Sex dimorphism, especially in length of the fins, seems to account for the differences noted by Myers between *snyderi*, the male (as checked for us by N. J. Wilimovsky), and *coulteri*, the female (all specimens from the Chignik River, including the fish figured by Myers, are females). Since there remains no adequate basis for specific separation, *Prosopium snyderi* is placed in the synonymy of *C. coulteri*.

The Committee on Names of Fishes has expressed its disapproval of patronymics (e.g., Coulter's whitefish) as common names (Transactions of the American Fisheries Society, Vol. 84. Of the two alternative names suggested for the species we prefer pygmy whitefish to brownback whitefish as being briefer, more suitably descriptive, and more euphonious. The name pygmy whitefish was introduced by Weisel and Dillon (1954).

DESCRIPTION

Diagnosis.—*Coregonus coulteri* (Fig. 1) agrees with other species of the subgenus *Prosopium* in having a single internarial flap, in the presence of parr markings on the body in the young, in lacking teeth on the jaws, vomer and palatine, and in the terete body. The anterior lateral-line scales have the exposed field subequal to or only slightly smaller than the adjacent body scales. The scales are large, 54 to 70 along the lateral line, 31 to 40 around the body, and 16 to 20 around the caudal peduncle; dorsal rays 10 to 14; pyloric caeca 15 to 23; vertebrae 52 to 54. The mouth is subterminal, the premaxillae are inclined downward and backward, and sometimes are almost vertical. The gillrakers number 13 to 20, and are short to moderate in length, measuring from 1.3 to 2.1 percent of the standard length. The snout is broadly rounded in dorsal view. The mouth is of

TABLE 2. — *Proportional measurements of Coregonus couleri, expressed in thousandths of standard length*
[Data for the holotype of *Prosopium Snyderi* are calculated from Myers (1932)]

Measurement	Lectotype ¹ <i>C. couleri</i>	Holotype, <i>P. Snyderi</i>	Bull Lake, Montana				Keweenaw Bay, Michigan			
			5 males		2 females		5 males		5 females	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
Standard length (millimeters).....	92.5	137.0	86-109	98	118-128	123	88-96	92	100-111	104
Dorsal origin to snout tip.....	465	467	438-486	463	453-463	458	470-480	474	467-483	477
Dorsal origin to caudal base.....	551	...	556-555	551	556-566	561	523-551	540	528-548	536
Dorsal origin to adipose origin.....	347	...	345-371	358	362-382	372	314-341	333	325-344	333
Pelvic insertion to snout tip.....	491	511	495-529	510	494-501	498	493-515	502	499-531	514
Pelvic insertion to caudal base.....	523	...	495-508	500	508-512	510	502-522	511	477-498	489
Pelvic insertion to anal origin.....	257	...	229-245	238	244-257	250	231-249	237	220-236	228
Body depth.....	172	212	180-199	187	178-206	192	188-219	200	199-225	212
Body width.....	...	...	101-113	108	107-134	120	98-113	106	111-128	118
Caudal peduncle length.....	176	153	151-167	160	166-168	167	153-182	170	145-176	163
Caudal peduncle depth.....	63	73	65-71	69	62-75	68	72-77	74	67-78	73
Head length.....	230	248	234-255	244	223-233	228	240-250	245	238-244	240
Head depth.....	132	153	135-143	140	131-137	134	123-134	128	130-149	141
Interorbital width.....	53	55	54-58	56	55-58	56	46-50	48	45-50	47
Snout length.....	58	66	56-64	60	56-60	58	54-60	57	58-61	59
Upper jaw length.....	68	62	68-79	74	63-66	64	67-75	70	65-72	69
Lower jaw length.....	65	55	65-70	67	55-60	58	70-73	71	67-71	69
Dorsal fin height.....	80	...	84-91	87	81-83	82	93-100	97	86-92	90
Adipose fin length.....	192	219	212-221	217	190-212	201	181-214	196	170-192	184
Anal fin height.....	86	...	83-101	90	94-96	95	81-96	88	83-91	88
Caudal fin length.....	184	197	173-203	186	165-172	168	160-163	161	141-156	147
Pectoral fin length.....	...	...	260-278	267	247-266	256	217-236	229	205-231	213
Pelvic fin length.....	197	234	194-200	198	177-193	185	171-190	183	160-173	165
Gillraker length.....	179	197	171-178	176	159-170	164	154-172	164	142-159	152
	13	...	17-21	18	16-18	17	15-17	16	14-16	15

¹ The lectotype has 11 dorsal rays (3 simple), 13 anal rays (4 simple), 16-16 pectoral rays, 10-9 pelvic rays, 59 scales along lateral line, 35 scales around the body in front of the dorsal fin, of which 14 are above the lateral lines and 19 below, 18 scales around the caudal peduncle, of which 8 are above and 8 below the lateral lines, and 5 + 1 + 9 = 15 gillrakers

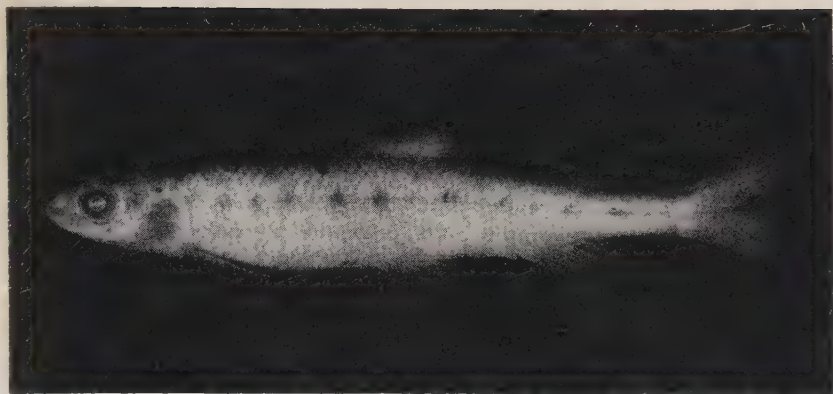


FIGURE 1.—*Coregonus coulteri*, a mature female, 4.8 inches long and 4 years old, collected October 15, 1953, in Keweenaw Bay, Lake Superior.

moderate size. The maximum total length recorded is less than 8 inches.

Description of Lake Superior stock.—Body proportions are presented in Table 2 and fin-ray, scale, and gillraker counts are given in Tables 3-7. *Coregonus coulteri* (Fig. 1) is apparently the smallest species of the genus; the largest specimen obtained in Lake Superior was 149 millimeters in total length although somewhat larger fish have been taken in the Pacific drainage (see Tables 15 and 17 for length distribution and size at maturity).

In measured specimens of the pygmy whitefish, females have large eggs and the body averages deeper and broader than in males (Table 2). The only other parts in which marked sex dimorphism is evident are the lengths (and heights) of the rayed fins; in all of these the males have the greater

TABLE 3.—*Frequency distributions of counts of dorsal and anal fin rays in Coregonus coulteri*

[All unbranched rays are included. N=number of specimens]

Locality	Dorsal rays					N	Mean	Anal rays					N	Mean
	10	11	12	13	14			11	12	13	14	15		
Alaska														
Lake Aleknagik.....	..	..	3	..	..	3	12.00	..	2	1	..	..	3	12.33
Chignik River.....	..	8	7	1	..	16	11.56	..	6	8	2	..	16	12.75
Columbia drainage														
Kicking Horse River..	..	5	4	..	..	9	11.44	1	2	5	1	..	9	12.67
Lower Arrow Lake...	..	1	1	..	..	2	11.50	..	1	1	..	..	2	12.50
Diamond Lake.....	..	2	..	..	..	2	11.00	..	1	1	..	..	2	12.50
Bull Lake.....	..	7	13	3	..	23	11.83	1	10	10	2	..	23	12.57
Lake McDonald.....	..	14	5	..	1	20	11.40	1	12	5	1	1	20	12.45
Lake Superior.....	5	23	2	..	..	30	10.90	..	1	18	6	..	25	13.20

TABLE 4. — Frequency distributions of counts of pectoral and pelvic fin rays in *Coregonus coulteri*

[Counts for right and left sides are summed. N=number of specimens]

Locality	Pectoral rays										N	Mean	Pelvic rays					N	Mean
	26	27	28	29	30	31	32	33	34	18			19	20	21	22			
Alaska																			
Lake Aleknagik				1	1	1	..	..	..	3	29.00	..	1	2	..	..	3	19.67	
Chignik River				1	2	6	4	3	..	16	30.38	4	4	6	1	..	15	19.27	
Columbia drainage																			
Kicking Horse River . . .				..	..	6	..	3	..	9	30.67	2	2	5	..	..	9	19.33	
Lower Arrow Lake				..	..	..	2	..	..	2	31.00	1	..	..	..	1	2	20.00	
Diamond Lake				..	..	2	..	..	..	2	30.00	..	1	1	..	..	2	19.50	
Bull Lake				..	1	3	4	10	2	3	31.78	..	1	22	..	..	23	19.96	
Lake McDonald				..	..	1	7	6	3	3	20	32.00	3	7	10	..	20	19.35	
Lake Superior	1	1	4	8	8	2	1	..	..	25	29.24	..	2	13	4	6	25	20.56	

TABLE 5. — Frequency distribution of lateral-line scale counts in *Coregonus coulteri*

[N=number of specimens]

Locality	Lateral-line scales																	N	Mean
	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70		
Alaska																			
Lake Aleknagik.....	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	2	3	67.67
Chignik River.....	..	..	..	..	1	..	1	2	2	..	4	2	2	..	1	..	1	16	63.75
Columbia drainage																			
Kicking Horse River...	..	..	..	1	..	3	..	..	3	..	2	..	..	..	..	..	..	9	60.89
Lower Arrow Lake.....	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	2	56.50
Diamond Lake.....	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	2	61.00
Bull Lake.....	..	..	..	1	2	4	4	3	4	4	1	..	..	..	..	..	..	23	60.70
Lake McDonald.....	..	..	4	2	4	2	2	2	1	1	1	1	..	..	..	..	..	20	59.20
Lake Superior.....	2	6	5	4	4	5	..	2	1	..	..	..	..	..	..	..	..	29	57.14

dimensions (Table 2). The increased size is presumably of adaptive significance since in breeding males (from Montana) these fins (as well as the head and body) are well supplied with nuptial tubercles; it is surmised that the fins function in the spawning embrace.

Like most other species of the subgenus *Prosopium*, *Coregonus coulteri* is terete; the body width is decidedly more than half the depth. Several related species (e.g., *C. cylindraceus*, *C. williamsoni*) have the snout notably shortened and conical, more or less sharply angulate in dorsal aspect (Koelz, 1929, p. 323, Fig. 12), in contrast to the bluntly rounded snout of the lake whitefish, *Coregonus clupeaformis*, and the size of the mouth is much smaller than in *clupeaformis*. The profile of the snout in *coulteri* is similar to that of *clupeaformis*, and the mouth is about the same size. The upper jaw of *coulteri* is contained in the head length 3.1-3.4 times (2.9-3.6 in *clupeaformis* from Lake Superior—data from Koelz, 1929); the

TABLE 6. — Frequency distributions of body-circumference and caudal-peduncle scales in *Coregonus coulteri*

[N = number of specimens]

Locality	Body-circumference scales										N	Mean	Scales around caudal peduncle					N	Mean
	31	32	33	34	35	36	37	38	39	40			16	17	18	19	20		
Alaska																			
Lake Aleknagik.....	..	..	..	1	..	2	..	..	..	..	3	35.33	..	..	..	..	3	3	20.00
Chignik River.....	..	..	2	9	2	2	1	..	..	..	16	34.44	1	1	13	1	..	16	17.88
Columbia drainage																			
Kicking Horse River..	..	..	..	..	3	..	3	1	1	1	9	37.00	..	2	5	2	..	9	18.00
Lower Arrow Lake....	..	1	..	..	1	..	..	..	..	..	2	33.50	..	..	2	..	..	2	18.00
Diamond Lake.....	..	..	1	..	1	..	..	..	..	..	2	34.00	..	..	2	..	..	2	18.00
Bull Lake.....	..	..	5	2	9	6	1	..	..	..	23	34.83	..	1	11	8	2	22	18.50
Lake McDonald.....	1	1	6	8	3	..	..	..	..	..	19	33.58	..	2	11	5	2	20	18.35
Lake Superior.....	..	..	3	1	5	7	2	3	..	..	21	35.62	..	..	3	7	14	24	19.46

TABLE 7. — Frequency distribution of gillraker counts in *Coregonus coulteri*

[Rudimentary rakers are included. N = number of specimens]

Locality	Number of gillrakers								N	Mean
	13	14	15	16	17	18	19	20		
Alaska										
Lake Aleknagik.....	2	..	1	..	..	..	..	..	3	13.67
Chignik River.....	3	5	5	2	1	..	..	..	16	14.56
Columbia drainage										
Kicking Horse River..	..	1	5	3	..	..	..	..	9	15.22
Lower Arrow Lake.....	1	1	..	..	..	..	..	..	2	13.50
Diamond Lake.....	..	..	..	1	1	..	..	..	2	16.50
Bull Lake.....	..	..	2	6	10	2	1	..	21	16.71
Lake McDonald.....	..	..	2	5	5	3	5	..	20	17.20
Lake Superior.....	..	..	..	1	6	17	13	3	40	18.28

lower jaw is contained in the head 2.3-2.6 times (2.4-2.7 times in *clupeaformis*).

Both simple and branched rays of the dorsal and anal fins vary in number, and the arbitrary designation of the first ray on the basis of length is also unsatisfactory. There are usually 3, occasionally 2 or 4, unbranched dorsal rays, and usually 8, sometimes 7 or 9, branched rays; the total dorsal count is 10 to 12, usually 11 (Table 3). There are usually 3 or 4, occasionally 5, unbranched anal rays and 9 or 10, infrequently 8, branched rays; the total anal rays number (12) 13 or 14. All of 10 specimens counted had 19 principal caudal rays (17 branched). The pectoral rays vary from 13 to 16, and the pelvic rays from 9 to 11 (Table 4).

The scales are the largest in the family Salmonidae (Tables 5-6). The lateral-line scales number 54 to 62. There are 33 to 38 body-circumference scales, of which 13 to 15 are above the lateral lines and 18 to 23 are below.

The scales around the caudal peduncle number 18 to 20, of which 8 or 9 are above the lateral lines and 8 or 9 are below. The breast and belly are fully covered with scales equal in size to those on the remainder of the body. Unlike *Coregonus cylindraceus*, the scales of the lateral-line row have the exposed field equal to or scarcely smaller than the scales of adjacent rows.

The gillrakers are rather short (6.5 to 8.8 percent of head length, 1.4 to 1.7 percent of standard length) but are relatively longer than in *C. cylindraceus*. The rakers number 5 to 7 on the upper limb, 1 at the angle, and 10 to 12, most often 11, on the lower limb. Total raker counts (all rudiments included) vary from 16 to 20 (Table 7). The branchiostegal rays in 10 specimens counted number 7-7 in 3, 8-7 in 1, and 8-8 in 6.

The small number of pyloric caeca, perhaps the most distinctive structural feature of *Coregonus coulteri*, has apparently escaped prior notice. Ten Lake Superior specimens yield the following counts: 15 (1 specimen), 16 (2), 17 (2), 18 (2), and 19 (3). Three fish from Lake McDonald, Montana, have 20, 21, and 23 caeca. All caeca are simple. The minimum number of caeca for any other whitefish in the Great Lakes is 87 to 117 in *Coregonus cylindraceus* (Koelz, 1929). In vertebral count, too, the pygmy whitefish has a lower count than is usual among salmonids. Ten specimens have the following counts: 52 (2), 53 (7), 54 (1). The range of counts tabulated by Koelz (1929) among Great Lakes whitefishes is from 55 (in *C. zenithicus* and *C. hoyi*) to 63 (in *C. clupeaformis* and *C. cylindraceus*).

In adults the jaws, vomer, and palatine are toothless. The tongue, however, typically has several well developed, immovable teeth. These are imbedded but are readily revealed by removal of the soft tissue. Two large specimens of *coulteri* from Lake Aleknagik, Alaska, lack teeth on the tongue, but an individual from the Upper Chignik River, Alaska, has lingual teeth. Examination of several specimens of *Coregonus cylindraceus* from Lake Superior indicates the presence in this species also of one or a few teeth on the tongue. Koelz (1929) found no teeth in the mouth of this species.

In preservation *Coregonus coulteri* is pale tan, immaculate below and dusted lightly with melanophores on the lateral and dorsal surfaces of head and body. Along the lateral line is a series of about 8 to 11 subcircular parr marks that are more or less diffuse near their margins in half-grown individuals and become very indistinct in large adults (Fig. 1). The back is similarly marked by an irregular series of about 12 to 14 dark spots. A few additional spots are often present on the dorsolateral surface. There is a dark bar on the preorbital bone that parallels the upper jaw, and there are usually 1 to 3 dark spots on the top of the head behind the eyes.

Geographic variation.—In view of the great phenotypic and probably genotypic variability among whitefishes, it is to be anticipated that a species with a discontinuous range as extensive as that of the pygmy whitefish would exhibit notable local or regional variations in structure. Such observed variations have furnished the basis for the naming of a plethora of

species and subspecies both in Eurasia and North America, with the addition of numerous infrasubspecies and even lesser named ranks among Old World coregonines. As expected, *Coregonus coulteri* is not structurally homogeneous throughout its range, but the strong similarity among the disjunct populations is more impressive than the relatively slight differences. Commonly the deviations present no consistent geographic pattern, giving rise to the suspicion that they are strictly local and represent genetic emphasis or reflect ecological differences rather than fundamental geographic divergence. More material, especially from the northwestern part of the range, is needed to resolve some aspects of the problem of geographic variation.

On the basis of the samples measured (Table 2), a number of body parts give evidence of variation. Notable among these are the lengths of the rayed fins, which also displayed sex dimorphism (p. 169). In each sex the fins of pygmy whitefish from Bull Lake, Montana, are higher (or longer) than those from Keweenaw Bay, Lake Superior. Only for the adipose fin do the differences seem to be of dubious reliability. The higher anal fin in the Bull Lake fish is especially notable. The type specimen of *Prosopium snyderi* is seen to agree closely with males of the Bull Lake stock in the dimensions of the median fins but has longer paired fins (it is possible that differences in mensural techniques are involved here). The lower jaw, and perhaps the upper jaw, average longer in the Lake Superior fish than in those from Bull Lake. The interorbital breadth is consistently greater in the Bull Lake whitefish. There are indications that the dorsal fin originates farther forward in the Bull Lake fish than in those from Keweenaw Bay, but the difference is slight, is subject to considerable overlap, and perhaps has no real significance.

In view of the notable differences in subsequent growth rate between stocks from Bull Lake and Keweenaw Bay (Fig. 4) there exists a strong possibility that early development, too, may differ in the same direction. If so, we may invoke a mechanistic explanation for the observed differences in fin and body proportions (Martin, 1949). Variations in developmental temperature are reflected in mean rate of growth and in size at which growth inflections occur. These in turn are important in the determination of the relative size of body parts, such as head and fins. In experimental lots of rainbow trout larger fins were produced by raising the temperature during early development (Martin, 1949).

Fin-ray counts of *Coregonus coulteri* (Tables 3-4) show some geographic variation in number of dorsal, anal, and pectoral rays but reveal nothing significant in pelvic-ray number. In the dorsal fin the usual number is 11 or 12 rays. At several localities these counts are equally frequent, but in Lakes McDonald and Superior there are usually 11 rays whereas in Bull Lake the modal count is 12. No consistent geographic pattern is suggested. In the anal fin 12 and 13 rays are most frequent, usually 12 rays in Lake McDonald and 13 in Lake Superior. A pectoral count of 16 is most frequent in Bull and McDonald Lakes, Montana. Elsewhere in the Columbia River drainage, in Alaska, and in Lake Superior, the most common count is 15.

In this as in the other fins, variation in the number of rays seems explainable as the result of local genetic emphasis or environmental modification. In any event the differences are not great, and the counts in the several populations overlap broadly.

There is no consistent positive correlation among the scale counts recorded (Tables 5-6). Lateral-line counts are maximal in Alaska, especially in Lake Aleknagik, are rather uniformly intermediate in the Columbia River system, and are lowest in Lake Superior. In the absence of certain of these stocks one might be inclined to recommend systematic partition of the others. In view of the rather complete gradation with extensive overlap between populations, however, such division seems pointless. Most populations usually have from 34 to 36 body-circumference scales, but the average number is considerably lower in McDonald Lake and higher in the Kicking Horse River—both in the Columbia basin. The most frequent caudal-peduncle scale count is 18 at all localities except Lake Aleknagik and Lake Superior, where counts of 19 and 20 are usual. As with the other counts the variations seem not to warrant special emphasis.

In the pygmy whitefish the number and the length of gillrakers are obviously correlated. In Alaska, the Kicking Horse River, and Arrow Lake the rakers are few (usually 13 to 16) and short (Table 7). Only one specimen was measured (Table 2), but the stubbiness of the rakers was noted during counting. In Diamond, Bull, McDonald, and Superior lakes the rakers typically number 16 to 19, and are notably longer (Table 2). Although there is overlap in numbers and probably in length, the differences in gillrakers are more marked than those in other characters. In view of the geographic implications, with some Columbia basin populations like the Lake Superior fish and others similar to Alaskan stocks, it seems improbable that each of the two structural types has a separate, monophyletic ancestry.

The acquisition by a lacustrine whitefish, even if it is a benthic form, of more and longer gillrakers is probably of adaptive advantage in obtaining food. It may be noted that the populations with the better developed and more numerous gillrakers are lacustrine. Three of the stocks with fewer rakers are from rivers or lakes dominated by rivers. If we assume that the species was chiefly a stream fish originally, it seems probable that relatively rapid parallel modification in two or more lakes has produced an increased length and number of gillrakers.

Comparisons with other species.—*Coregonus coulteri* was regarded by Evermann and Smith (1896) as the most distinctive of the North American members of the genus, a characterization which is still at least close to correct. Among the species of American coregonines, *coulteri* is the smallest, has the largest scales, the minimal number of gillrakers (13 to 20, about as in *cylindraceus*), the fewest vertebrae, and has only about one-fourth as many pyloric caeca as the lowest number reported among its congeners. The most obvious differences between the pygmy whitefish and the round whitefish, *C. cylindraceus*, are set forth in Table 8. Many of these same characters serve also to distinguish *coulteri* from the Rocky

TABLE 8.—Comparison of the two species of the subgenus *Prosopium* in the Great Lakes area

[Proportional measurements, calculated arithmetically, are based on 10 specimens of *Coregonus coulteri*, 74 to 107 millimeters in standard length, from Keweenaw Bay, and 10 individuals of *C. cylindraceus*, 236 to 377 millimeters long, from Lake Superior (Koelz, 1929: p. 632). Data for *C. cylindraceus* that are taken wholly or in part from Koelz (1929) are indicated by asterisks]

Character	<i>Coregonus coulteri</i>	<i>Coregonus cylindraceus</i>
Scales along lateral line	(55) 56-66 (70)	¹ (80) 83-96 (100)*
Scales around body	(31) 33-37 (40)	(40) 42-46 (47)*
Scales around caudal peduncle	(16) 18-20	22-24
Size of exposed field of anterior lateral-line scales	Subequal to adjacent scales	Notably smaller than adjacent scales (scarcely smaller in small juveniles)
Vertebrae	52-54	59-63*
Pyloric caeca	15-23	87-117*
Pelvic fin rays	9-10 (11)	(10) 11 (12)
Dorsal fin rays	(10) 11-13 (14)	(13) 14-15
Upper jaw length in head length	3.1 to 3.4	3.9 to 4.8*
Mandible length in head length	2.3 to 2.6	2.7 to 3.1*
Gillraker length in head length	11.4 to 15.4	19.6 to 27.2*
Pelvic fin length in distance from pelvic insertion to anal origin	1.3 to 1.7	1.7 to 2.5*
Size	Small; maximum total length 149 millimeters (Lake Superior) to ca. 198 millimeters (Alaska)	Large; maximum weight about 5 pounds*

¹Koelz (1929, p. 562) recorded a Lake Superior specimen of *cylindraceus* with 74 scales, 10 fewer than his next lowest count from the lake. It is conceivable that this was a hybrid with *coulteri*

Mountain whitefish, *C. williamsoni*. That species has longer and more numerous gillrakers, numbering 20 to 25, than do *coulteri* and *cylindraceus*.

DISTRIBUTION AND ABUNDANCE

General distribution.—The known range of the pygmy whitefish is confined to Lake Superior and certain waters on the Pacific slope from the headwaters of the Columbia River to south-central Alaska (Fig. 2). The species has not been collected in the Great Lakes other than Lake Superior. Trawling by the *Cisco* in northern and western Lake Huron in September and October 1952, was too limited to preclude the possibility of its occurrence there. It was not collected in much more extensive trawling in Green Bay, Lake Michigan, May 29–October 26, 1952, in southern Lake Michigan May 8, 1954–March 10, 1955, and in northern Lake Michigan May 14–September 7, 1955. The pygmy whitefish apparently either does not occur or is rare in these waters.

It may be anticipated that future investigation will yield additional records of the pygmy whitefish in the cold streams and deep lakes of the Pacific drainage from the Columbia River system to south-central Alaska. There is as yet no evidence of the existence of the species in the Mackenzie River basin, but it may possibly occur in deep lakes there as it does in Lake Superior. That the pygmy whitefish exists in northern United States or southern Canada, between Lake Superior and the Columbia River drain-

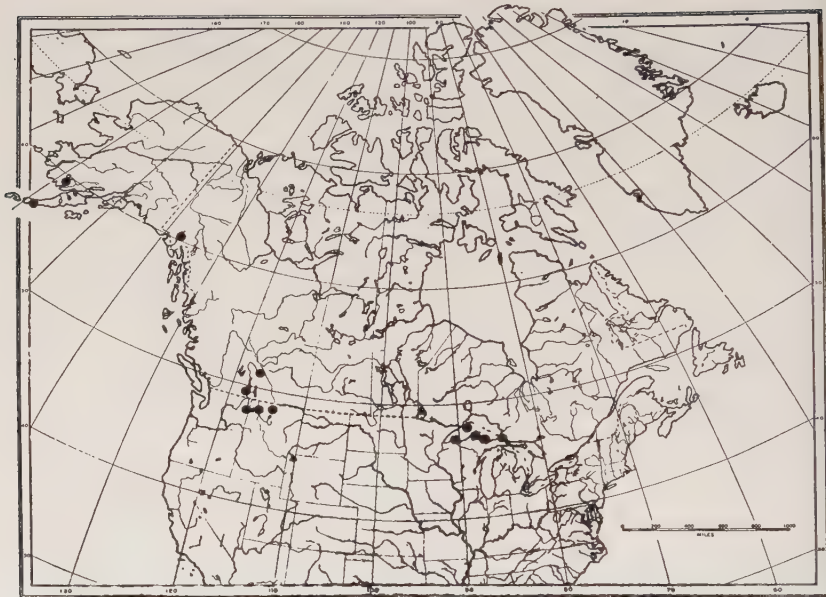


FIGURE 2.—Northern North America, showing collection localities for the pygmy whitefish.

age, however, seems unlikely. This region has been fairly well investigated and has few if any waters suitable to the species.

It is probable that *Coregonus coulteri* was a common and continuously distributed species near the periphery of the ice in late Pleistocene time. The few relict populations known to persist occupy some of the coldest waters of the United States, western Canada, and Alaska. Thus the present disjunct distribution may be regarded as due to survival in suitable habitats following the retreat of the Wisconsin glaciation. The results of radiocarbon analyses have demonstrated the relative recency of the last glaciation (Hough, 1953; Zumberge and Potzer, 1955). Hence, the finding that widely separated stocks of the pygmy whitefish differ little morphologically has a rational historical explanation. If the isolation of stocks was temporally remote, substantial structural differentiation would be expected.

Distribution and abundance in Lake Superior.—In Lake Superior the pygmy whitefish is widely distributed. Collection localities range from the Apostle Islands east to Whitefish Bay (about 290 miles) and north to Isle Royale (Fig. 3, Table 1). The species unquestionably occurs elsewhere. Collecting was restricted to areas with a suitable bottom for trawling where commercial fishing gear was not in use. No trawling was attempted along the entire northern and most of the eastern shore of the lake.

Although relatively few pygmy whitefish have been collected in other waters, Lake Superior has yielded 1,623 specimens. Of these, 68 percent

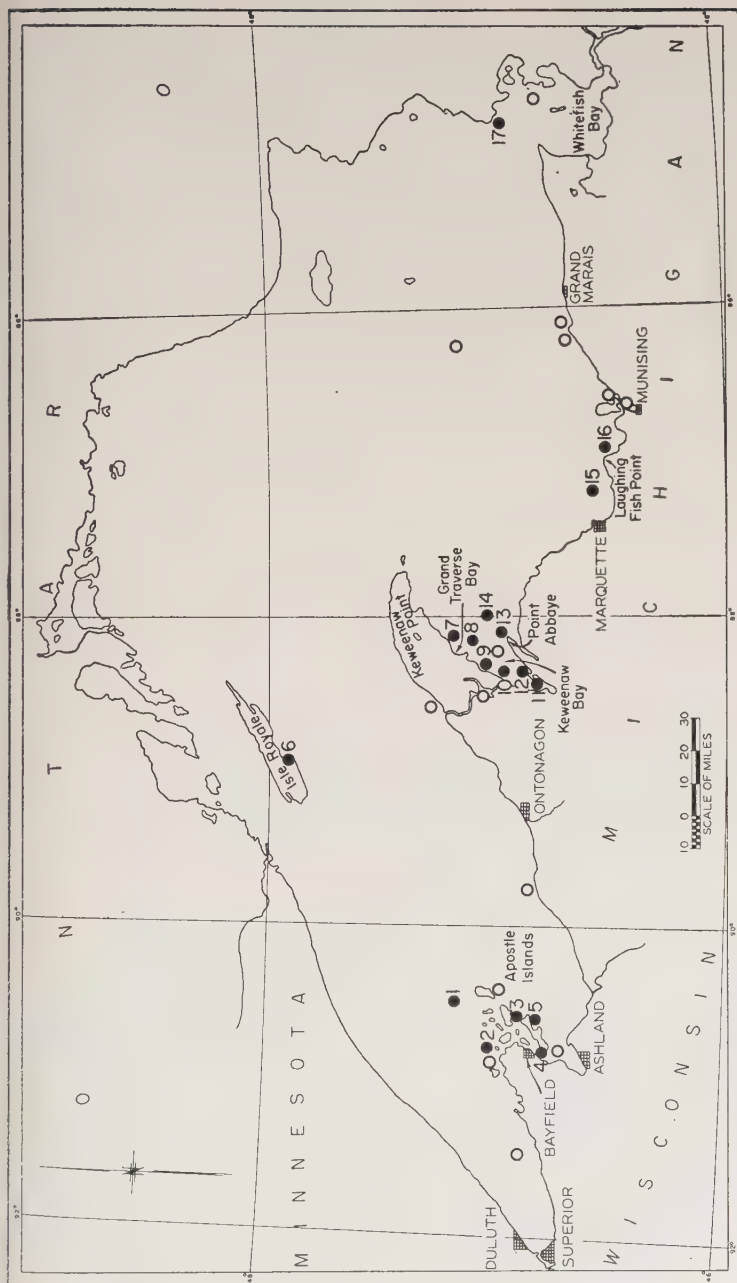


FIGURE 3.—Lake Superior, showing collecting stations (solid circles) for the pygmy whitefish and localities of special interest in this study. Open circles indicate trawling stations where the species was not taken.

were obtained in Keweenaw Bay (Fig. 3, Stations 9 to 12), 23 percent in Siskiwit Bay, Isle Royale (Station 6), 4 percent off Laughing Fish Point (Station 16), 2 percent in the Apostle Islands (Stations 1 to 5), and the remaining 3 percent at other localities. The number of fish taken at the several stations is not directly indicative of the abundance in these areas because of variation in fishing time. Nevertheless, the pygmy whitefish was more plentiful in Siskiwit Bay and in Keweenaw Bay than elsewhere. In Siskiwit Bay as many as 171 fish were collected in a single 10-minute haul (more than 80 percent were young of the year), and the average in the area was 52 per haul. In Keweenaw Bay (Stations 9 to 12) 85 were obtained from a single haul and the average catch in 74 drags was 15 fish. The maximum catch per haul did not exceed 15 at other stations, except for 20 fish taken in a 9-minute haul at Station 14. At two of the *Cisco's* major collection areas, the Apostle Islands and Laughing Fish Point, the average catch on dates when pygmy whitefish were taken was only 2 per haul.

Pygmy whitefish were not collected at 14 stations fished during 1953. The open circles of Figure 3 designate localities at which a minimum of 20 minutes of trawling failed to collect the species, even though the catch of other fish indicated that the trawl was operating satisfactorily. Trawling at 9 of these stations was at depths above, below, or near the limits of the known bathymetric distribution of *Coregonus couleri* in Lake Superior. Comparison of localities of proper depth indicates that trawling was successful chiefly in a protected habitat. Three of the 5 unsuccessful stations of suitable depth are in exposed situations; 3 of the 4 major sampling areas (Siskiwit and Keweenaw Bays, Apostle Islands) are well protected, and the other (Laughing Fish Point) is partly protected from prevailing winds. In exception to this apparent preference for a protected habitat, the pygmy whitefish was not caught in Munising Bay, Munising, Michigan. Here about 2 hours of trawling on June 17-22 at depths of 15-39 fathoms failed to take pygmy whitefish, but the lake whitefish was far more abundant than at any other locality fished.

BATHYMETRIC DISTRIBUTION

The bathymetric range of the pygmy whitefish at Station 11 in southern Keweenaw Bay (Fig. 3), where 58 percent of our specimens were obtained, extended from 10 to 49 fathoms (Table 9). Although taken at all depths fished, it was most plentiful at 25-39 fathoms; the average maximum rate of capture (37 per 10-minute haul) was at the 30- to 34-fathom interval. The distribution was similar throughout the season, but on August 2 many fish were taken at 15-19 fathoms, and on May 11 the only fish caught were at 45-49 fathoms. This latter collection indicated a distribution similar to that at Laughing Fish Point (Station 16) early in 1954. There, on January 11, 40 minutes of trawling at 43-54 fathoms yielded 5 pygmy whitefish, whereas 30 minutes of fishing at the same station on January 7 at 26-40

TABLE 9. — *Numbers of pygmy whitefish captured per 10-minute drag of an otter trawl in southern Keweenaw Bay (Station 11), Lake Superior, 1953*
 [Number of minutes of trawling in parentheses]

Depth ¹ (fathoms)	May 11	July 11	August 2	September 11	October 2-3	October 15	Average
10-14.....	...	...	0.5 (20)	0.0 (10)	...	3.0 (10)	1.0 (40)
15-19.....	...	...	22.0 (20)	4.0 (10)	0.0 (10)	...	12.0 (40)
20-24.....	...	...	...	2.0 (10)	14.5 (20)	1.5 (20)	6.8 (50)
25-29.....	...	0.0 (10)	19.7 (30)	24.9 (35)	...	23.3 (75)	21.4 (150)
30-34.....	...	41.5 (20)	19.2 (40)	54.4 (39)	32.3 (13)	...	37.0 (112)
35-39.....	0.0 (6)	...	7.0 (10)	...	...	51.0 (10)	22.3 (26)
40-44.....	0.0 (58)	...	...	40.0 (10)	...	10.0 (20)	6.8 (88)
45-49.....	0.6 (65)	...	...	...	...	...	0.6 (65)

¹ Placement of individual hauls based on the mean of the shallowest and deepest water fished. Most tows paralleled isobaths in water of nearly constant depth

fathoms failed to take the species. Perhaps pygmy whitefish are confined to waters of considerable depth during the winter and spring.

The average length of pygmy whitefish increased directly with water depth in southern Keweenaw Bay in 1953 (Table 10). Mean total lengths in the combined collections ranged from 71 millimeters (2.8 inches) at 10–19 fathoms to 116 millimeters (4.6 inches) at 40–49 fathoms. (The trend was similar in individual collections.) This relationship was caused by differences in the depth distribution of age groups. All fish collected at the shallowest interval (10–14 fathoms) were yearlings; the percentage of fish of this age declined with increase in depth to 7 percent at 40–44 fathoms and nil at 45–49 fathoms.

Some seasonal change occurred in the bathymetric distribution of I-group pygmy whitefish. At depths greater than 29 fathoms, the percentage of I-group fish taken within a specific 5-fathom depth interval increased somewhat with the progress of the season. At the 30- to 34-fathom interval, for example, yearlings made up only 16 percent and 14 percent of the catch on July 11 and August 2, but accounted for 32 percent on September 11 and 65 percent on October 2–3. At 35–39 fathoms the percentage of I-group whitefish was nil on August 2 and 16 on October 15; at 40–44 fathoms it was 5 on September 11, and 11 on October 15. These increases

TABLE 10.—Average total length (millimeters) of pygmy whitefish caught at different depths in southern Keweenaw Bay (Station 11) Lake Superior, 1953

[Number of fish in parentheses. Data presented are from preserved fish; 83 were discarded]

Depth (fathoms)	May 11 ¹ July 11	August 2	September 11	October 2-3	October 15	Average	Percentage of yearlings in catch
10-14.....	...	69 (1)	...	...	80 (3)	77 (4)	100
15-19.....	...	70 (39)	76 (2)	...	...	70 (41)	95
20-24.....	...	...	...	84 (22)	78 (3)	83 (25)	72
25-29.....	...	103 (59)	87 (105)	...	94 (171)	93 (335)	49
30-34.....	102 (81)	105 (28)	99 (192)	89 (34)	...	99 (335)	30
35-39.....	...	116 (7)	...	...	104 (50)	105 (57)	14
40-44.....	...	...	118 (40)	...	113 (19)	116 (59)	7
45-49.....	116 (4)	...	...	...	...	116 (4)	0

¹ The collection at 30-34 fathoms was made July 11; that at 45-49 fathoms on May 11² Includes 17 fish collected at 30 fathoms and 2 fish from 21 fathoms

in percentage of I-group fish are reflected in the mean lengths of Table 10. Yearlings collected at different depths on the same date showed no significant difference in average length.

The rate of capture of pygmy whitefish on September 7 in Siskiwit Bay (Station 6) was slightly higher at 15-19 and 20-24 fathoms (23 and 24 fish per haul) than at 35-39 fathoms (17 fish per haul). On September 30 more fish were taken in a haul at 10-14 fathoms (171) than at 15-19 fathoms (95), the only depths fished. Most were 0- or I-group fish. Data for collections at other stations in Lake Superior were too scanty for analysis but indicated a vertical distribution according to size and age similar to that in Keweenaw Bay.

AGE AND GROWTH

Age was determined for 271 pygmy whitefish collected in Keweenaw Bay (Station 11) on October 2 and 15, 1953, 94 caught in Siskiwit Bay (Station 6) on September 7, 32 taken in the Apostle Island region (Stations 2-5) on May 30-July 30, and 37 from Laughing Fish Point (Station 16), July 13, 1953-January 11, 1954. Scales were mounted in a glycerin-gelatin medium and diameters within annuli were measured at the magnification $\times 84$. Growth calculations were by direct proportion.

Keweenaw Bay.—Calculated total lengths at the end of each year of life for 123 male and 148 female pygmy whitefish from Keweenaw Bay (Table 11) reveal extraordinarily slow growth. The two oldest fish, both nearing the end of their eighth growing season, were only 5.4 inches long at the time of collection.

TABLE 11. — *Average calculated total length (millimeters) and length at capture of pygmy whitefish collected in Keweenaw Bay, October 2 and 15, 1953*

Age group	Sex	Number of fish	Total length at capture		Weight (grams)	Calculated length at end of year of life						
			Inches	Millimeters		1	2	3	4	5	6	7
I	Male.....	61	3.0	76	2.3	54	..	..	..	..	..	..
	Female.....	57	3.0	77	2.4	55	..	..	..	..	..	..
II	Male.....	14	3.7	94	4.7	42	76	..	..	..	..	..
	Female.....	15	4.0	101	6.1	36	76	..	..	..	..	..
III	Male.....	5	4.0	102	5.9	42	75	95	..	..	..	..
	Female.....	10	4.2	106	7.5	40	75	92	..	..	..	..
IV	Male.....	25	4.2	106	7.8	44	69	87	99	..	..	..
	Female.....	26	4.7	120	12.9	42	69	91	111	..	..	..
V	Male.....	18	4.3	110	8.8	44	70	86	97	106	..	..
	Female.....	35	5.0	126	15.2	41	65	86	104	118	..	..
VI	Female.....	3	5.0	128	16.1	46	68	90	105	115	123	..
VII	Female.....	2	5.4	136	20.4	37	60	79	95	110	122	130
Average increment	Male.....	123	...	...	...	49	28	17	12	9	...	...
	Female.....	148	...	...	...	46	29	21	19	14	10	8
Average length	Male.....	123	...	...	...	49	71	87	98	106	...	...
	Female.....	148	...	...	...	46	69	88	107	117	123	130
Increment of average	Male.....	123	...	...	...	49	22	16	11	8	...	...
	Female.....	148	...	...	...	46	23	19	19	10	6	7

Female pygmy whitefish consistently averaged longer and heavier at capture than did males of the same age. The difference in length ranged from 1 millimeter (I group) to 16 millimeters (V group); the weight advantage of the females varied from 0.1 gram (I group) to 6.4 grams (V group). In age-group V, females were 73 percent heavier than males. The annual increments of length indicate a first-year advantage for males (49 millimeters as compared with 46 millimeters for females), nearly equal growth in the second year (28 and 29 millimeters), and more rapid growth for females in the next 3 years. The calculated lengths for the age-groups exhibit some indication of "Lee's phenomenon." Except for the first-year length of age-group I the trend is not sharp, but it is sufficient to produce discrepancies between average increments and increments of the average (Table 11). Comparison of lengths at collection and calculated lengths of fish of the various age groups indicates that the growing season may have been nearly completed by the date of collection.

Despite irregularities in the data, the percentage of males decreased with age. Males made up 51 percent of the fish in age-groups I and II, 45 percent of those in age-groups III and IV, and only 31 percent of age-groups V-VII (only females in VI and VII groups). This trend is reflected in the average age (number of annuli) which was 2.4 for males and 2.9 for females. The complete sample was 45 percent male.

The poor numerical representation of age-groups II and III (in comparison with age-groups I, IV, and V) suggests that year-classes 1950 and 1951 may have been relatively weak. Wide fluctuations in the strength of year classes have been observed frequently in Great Lakes fishes (including coregonines). The small numbers of whitefish in age-groups VI and VII may result from normal mortality rather than weakness of year classes.

With the exception of age-groups I and II, the length-frequency distribution at the time of collection of adjacent age groups of pygmy whitefish in Keweenaw Bay exhibited extensive overlap (Table 12). Length alone,

TABLE 12. — Length-frequency distribution of age groups of pygmy whitefish collected in Keweenaw Bay, October 2 and 15, 1953
[M=male; F=female]

Total length		I		II		III		IV		V		VI	VII	Total		
Inches	Millimeters	M	F	M	F	M	F	M	F	M	F	F	F	M	F	Both sexes
2.2-2.3	55- 59	..	1	..	..	..	..	..	..	..	..	..	..	..	1	1
2.4-2.5	60- 64	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
2.6-2.7	65- 69	5	3	..	..	..	..	..	..	..	..	..	..	5	3	8
2.8-2.9	70- 74	19	15	..	..	..	..	..	..	..	..	..	..	19	15	34
3.0-3.1	75- 80	27	22	..	..	..	..	..	..	..	..	..	..	27	22	49
3.2-3.3	81- 85	8	13	..	..	..	..	..	..	..	..	..	..	8	13	21
3.4-3.5	86- 90	2	3	3	..	..	..	..	..	..	..	..	..	5	3	8
3.6-3.7	91- 95	..	..	5	2	..	..	..	..	..	..	..	..	5	2	7
3.8-3.9	96-100	..	..	5	5	2	3	5	..	..	..	..	..	12	8	20
4.0-4.1	101-105	..	..	1	6	1	1	7	..	5	..	..	..	14	7	21
4.2-4.3	106-110	..	..	..	2	2	2	11	..	3	..	..	..	16	4	20
4.4-4.5	111-115	..	..	..	..	..	4	2	5	9	1	..	..	11	10	21
4.6-4.7	116-120	..	..	..	..	..	..	10	1	2	..	..	..	1	12	13
4.8-4.9	121-125	..	..	..	..	..	..	7	..	14	1	..	..	..	22	22
5.0-5.1	126-130	..	..	..	..	..	..	3	..	13	1	..	..	..	17	17
5.2-5.3	131-135	..	..	..	..	..	..	1	..	4	1	1	1	..	7	7
5.4-5.5	136-140	..	..	..	..	..	..	..	..	1	..	1	1	..	2	2
Total.....		61	57	14	15	5	10	25	26	18	35	3	2	123	148	271

therefore, can be employed with confidence for the identification of all but the largest fish (3.4-3.5 inches) in the I-group but at greater age is undependable. Every length interval beginning with 3.8-3.9 inches included members of 2 to 4 age groups.

Siskiwit Bay, Isle Royale.—The growth rate of pygmy whitefish was even slower in Siskiwit Bay (Table 13) than in Keweenaw Bay. With the exception of the second year of life all calculated annual increments of length were greater in Keweenaw Bay than in Siskiwit Bay. The maximum

difference in rate was in the fourth year of life of females (11 millimeters in Siskiwit Bay; 19 millimeters in Keweenaw Bay). Despite the more rapid growth in Keweenaw Bay, the data for the two stocks exhibit certain similarities. In both areas, for example, females were larger than males at capture (exception in I-group of Siskiwit Bay). Sex differences of calculated growth also were similar. Males had the higher first-year increments, the growth of the sexes was nearly equal in the second year, and females had the greater increments in later years of life.

TABLE 13. — Average calculated total length (millimeters) and length at capture of pygmy whitefish collected in Siskiwit Bay, Isle Royale, September 7, 1953

Age group	Sex	Number of fish	Total length at capture ¹		Calculated length at end of year of life			
			Inches	Millimeters	1	2	3	4
O	Unknown.....	12	1.4	36	..	..	..	..
I	Male.....	17	2.5	63	42	..	..	..
	Female.....	10	2.3	59	41	..	..	..
II	Male.....	22	3.1	78	38	68	..	..
	Female.....	5	3.2	81	37	67	..	..
III	Male.....	18	3.3	85	39	68	81	..
	Female.....	11	3.5	88	32	62	80	..
IV	Male.....	1	3.6	92	46	72	81	88
	Female.....	10	3.9	100	39	65	85	96
Average increment	Male.....	58	...	...	40	29	13	7
	Female.....	36	...	...	37	28	19	11
Average length	Male.....	..	...	...	40	68	81	88
	Female.....	..	...	...	37	64	82	96
Increment of average	Male.....	..	...	...	40	28	13	7
	Female.....	..	...	...	37	27	18	14

¹ These fish were not weighed because they had been transferred from formalin to alcohol after collection

The sex ratio of Siskiwit Bay fish varied erratically among the age groups, but the oldest (IV) was strongly dominated by females. The numerical abundance of the age groups gives no indication of weakness in the 1950 and 1951 year classes, both of which were poorly represented in Keweenaw Bay.

The Apostle Islands.—The limited collection of pygmy whitefish from the Apostle Islands shows that growth was more rapid in this region than in Siskiwit or Keweenaw Bay. The average calculated total lengths in millimeters at the end of each year of life³ for 32 fish collected May 30–July 30, 1953, are shown below (number of fish in parentheses):

³ All age groups were combined. Because of difficulty in determining whether a new annulus had formed on scales of some fish collected May 30, only average lengths computed from scale measurements within visible annuli are included in the table.

		<i>Calculated length at end of year of life</i>						
		<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>
<i>Trawl collection</i>								
Males	50	75	95	108	.....	.....	.....	.....
	(6)	(5)	(5)	(2)	.....	.....	.....	.....
Females	46	72	94	112	122	126	136	136
	(21)	(21)	(20)	(16)	(9)	(4)	(3)	(3)
<i>Gill-net collection</i>								
Females	44	68	98	117	129	139	144	144
	(5)	(5)	(5)	(5)	(5)	(5)	(2)	(2)

The growth pattern for the sexes was similar to that described for Siskiwit and Keweenaw Bays. The average length of fish from trawl collections in the Apostle Islands was greater than that of fish from Keweenaw Bay (Table 11) for both sexes and at all ages, with the single exception of females at the end of the first year. Differences in rate of growth in these two regions were of about the same magnitude as differences in rate of growth between Keweenaw and Siskiwit Bays.

The single gill-net collection of pygmy whitefish is shown separately from trawl collections because the gill nets (1-inch mesh, extension measure) were obviously selective for fast-growing fish of large size. That this species attains a larger size in the Apostle Islands than elsewhere in Lake Superior is suggested by its capture in gill nets in this area only although other localities were fished with identical gear. Whereas 900 feet of 1-inch-mesh gill net captured 6 fish at this station, 27,600 feet of net set within the known bathymetric range of the species at other localities failed to take it. A total of 8,400 feet of this net was set in the Keweenaw Bay region, where the species was known to be abundant.

Laughing Fish Point.—The collection of pygmy whitefish from Laughing Fish Point for which ages were determined was limited to 25 fish of the I-group, and only 12 of other age groups. Despite minor discrepancies, presumably because of the small sample, a growth rate similar to that in Keweenaw Bay is indicated. A summary of the data for fish of age groups I to VI follows (number of fish in parentheses):

		Calculated length at end of year of life					
		1	2	3	4	5	6
Males	48	79	92	102	106	.....	.....
	(22)	(6)	(3)	(3)	(1)	.....	.....
Females	46	68	90	106	118	123	123
	(15)	(6)	(5)	(4)	(2)	(1)	(1)

As in the other regions calculated length of females was less than that of males for the first two years, about equal during the third, and exceeded that of males for the fourth and later years of life.

Length of young of the year.—Collections of young-of-the-year pygmy whitefish in Lake Superior indicated that fish of this age were showing good growth during September and October (Table 14). Although the

numbers of fish collected were usually small, their average lengths showed a progressive increase from 36 and 35 millimeters on September 7 and 10, to 45 and 49 millimeters on October 5 and 21.

Growth in Bull and McDonald Lakes, Montana.—That growth rate of pygmy whitefish was faster in Bull and McDonald Lakes, Montana, than in Lake Superior is shown by the curves of Figure 4, which compare cal-

TABLE 14. — *Length of O-group pygmy whitefish in Lake Superior, 1953*

Collection locality ¹	Date	Number of fish	Total length (millimeters)	
			Range	Average
Keweenaw Bay (9).....	Sept. 5	1	....	31
Siskiwit Bay (6).....	Sept. 7	12	32-40	36
Point Abbaye (13).....	Sept. 10	5	31-39	35
Laughing Fish Point (16).....	Sept. 14	13	33-39	37
Siskiwit Bay (6).....	Sept. 30	137	35-49	42
Laughing Fish Point (16).....	Oct. 5	9	40-54	45
do.....	Oct. 21	3	47-51	49

¹ Station numbers (Fig. 3) are in parentheses

culated lengths at the end of each year of life for fish from these waters and from Keweenaw and Siskiwit Bays. Data for fish from the Montana waters are as follows (number of fish in parentheses):

<i>Lake McDonald</i>	<i>Calculated length at end of year of life ⁴</i>			
	1	2	3	4
Males	64 (26)	88 (26)	101 (23)	108 (2)
Females	62 (6)	92 (6)	108 (6)	.....
<i>Bull Lake</i>				
Males	59 (20)	113 (20)	130 (10)	.....
Females	60 (2)	119 (2)	152 (2)	.....

At the age of 3 years, the average length of male pygmy whitefish from Bull Lake was 60 percent greater than in Siskiwit Bay; for females this percentage was 85. The increment during the second year of life, which showed the widest deviation, was nearly double that of Lake Superior fish. Almost no change in growth rate was shown by the fish from Bull Lake during the first 2 years of life, whereas this rate declined about 40 percent during the second year in Keweenaw Bay. An even sharper decline (about

⁴ Since the dates of collection were December 26 and January 12 (Bull Lake) and November 17 (Lake McDonald), an annulus at the periphery of the scales was assumed and length at collection was considered equivalent to calculated length.

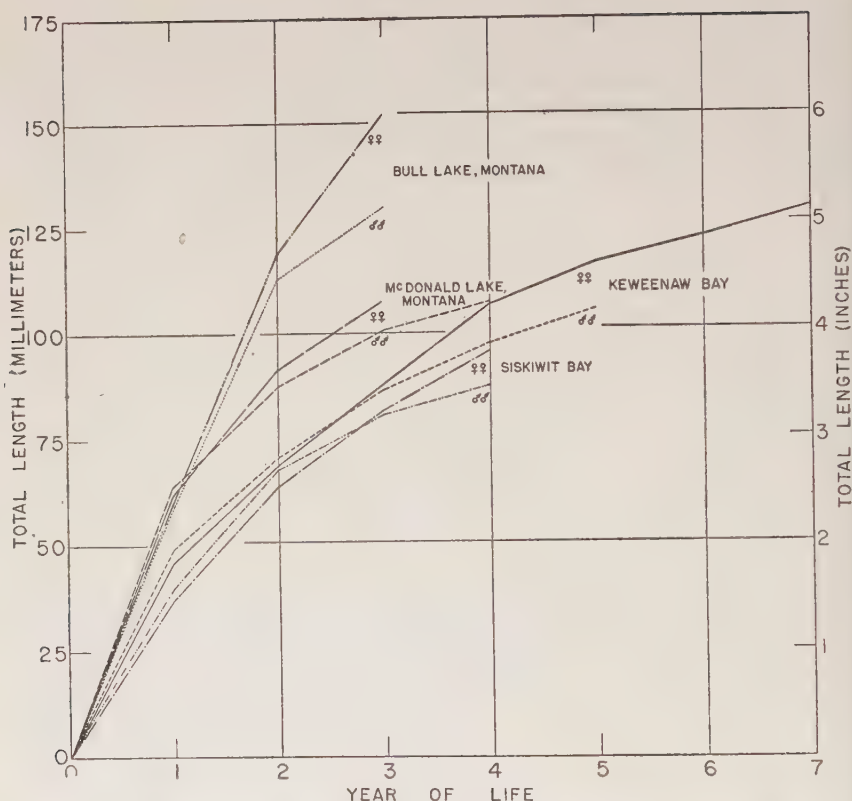


FIGURE 4.—Calculated growth in length of pygmy whitefish from Bull and McDonald Lakes, Montana, and Keweenaw and Siskiwit Bays, Lake Superior.

55 percent) in growth rate during the second year was indicated by pygmy whitefish of the Lake McDonald collection. Although these fish attained a first-year calculated length slightly greater than that of fish from Bull Lake, their growth curves during subsequent years were roughly parallel with those of fish from Lake Superior.

LENGTH-FREQUENCY DISTRIBUTION

The length-frequency distribution of 1,521 pygmy whitefish collected in Lake Superior in 1952–1954 (Table 15) is given separately for the four principal areas of capture. Collections from Keweenaw Bay and vicinity are tabulated in part according to sex and date.

The total length of pygmy whitefish taken by trawling in Lake Superior ranged from 1.2 to 5.7 inches. Only the young of the year and yearlings stood out reasonably well in the length-frequency distribution. The O group

TABLE 15. — Length-frequency distribution of pygmy whitefish collected by trawling in Lake Superior, 1952-1954
[M = male; F = female]

Total length (inches)	Keweenaw Bay and vicinity (Stations 7 to 14)								Total ¹	Siskiwi Bay (Station 6) Sept. 7-30, 1953	Laughing Fish Point (Station 16) July 13, 1953-Jan. 11, 1954	Apostle Islands (Stations 1-5) Aug. 20, 1952 and May 30- July 30, 1953	All fish ²
	May 7 July 11, 1953		Aug. 2, 1953		Sept. 5-11, 1953		Oct. 2-15, 1953						
	M	F	M	F	M	F	M	F					
1.2-1.3.....	...	...	...	...	...	...	...	...	3	5	2	...	10
1.4-1.5.....	...	...	...	...	...	...	...	...	3	23	11	...	37
1.6-1.7.....	...	...	...	...	...	...	...	...	...	96	6	...	102
1.8-1.9.....	...	...	...	...	...	...	...	...	...	25	3	...	28
2.0-2.1.....	...	1	...	...	...	...	...	...	1	2	3	...	6
2.2-2.3.....	...	...	...	...	...	...	...	...	1	4	...	...	5
2.4-2.5.....	6	...	...	...	...	...	...	...	17	27	3	...	47
2.6-2.7.....	9	10	13	11	...	1	...	...	88	62	1	...	151
2.8-2.9.....	19	9	9	6	30	18	21	23	164	46	5	1	216
3.0-3.1.....	1	...	5	1	38	21	40	33	153	28	14	...	195
3.2-3.3.....	1	...	...	...	5	1	14	17	40	14	5	...	60
3.4-3.5.....	3	4	1	2	2	1	4	3	22	23	...	...	47
3.6-3.7.....	7	3	6	2	10	4	6	3	45	7	3	2	57
3.8-3.9.....	7	7	11	3	16	9	13	8	86	5	1	1	93
4.0-4.1.....	6	3	6	2	27	7	14	7	77	4	...	2	83
4.2-4.3.....	8	2	3	4	18	6	17	4	64	1	2	1	68
4.4-4.5.....	1	4	2	9	10	12	11	10	62	...	2	3	72
4.6-4.7.....	...	11	...	10	3	21	1	13	64	...	2	6	83
4.8-4.9.....	...	9	...	13	...	32	...	22	79	...	1	3	52
5.0-5.1.....	...	5	...	6	...	18	...	17	47	...	1	3	29
5.2-5.3.....	...	4	...	2	...	10	...	7	25	...	...	4	11
5.4-5.5.....	...	1	...	...	...	2	...	2	8	...	...	3	2
5.6-5.7.....	...	...	...	...	...	1	...	...	1	...	...	1	...
Total.....	68	73	58	76	160	181	149	175	1,050	372	65	30	1,521
Average length.....	3.3	4.0	3.4	4.0	3.6	4.1	3.5	3.9	3.7	2.4	2.7	4.7	3.4

¹ Includes 110 fish for which sex is not given. Of these, 20 were caught August 16, 1952

² Includes 1 fish from Station 15 and 3 from Station 17 not shown elsewhere in table. Of 1,623 pygmy whitefish collected, 102 were not measured

was well separated from the I group in the Keweenaw Bay and Laughing Fish Point regions, but in the slowly growing population of Siskiwit Bay it tended to overlap the I group slightly by September 30 (all fish less than 2.0 inches long were of the O group). In Keweenaw Bay age-group I was reasonably distinct from older age groups in the collections of May 7 to August 2 (all fish less than 3.2 inches), and September 5-11 (less than 3.4 inches), but by October the largest of the yearlings had overtaken the smallest fish of the II group. Probably the demarcation of the I group would have been even less distinct if age-groups II and III had been represented by strong year classes; both were rather poorly represented in 1953. In Siskiwit Bay, where age-groups II and III were well represented, the length-frequency distribution of age-group I overlapped broadly those of older age groups.

Separation of males from females in the length-frequency distribution for pygmy whitefish from Keweenaw Bay emphasizes the sexual differences in growth rate and life span (p. 181). All fish longer than 4.7 inches were females (Table 15), except for a 5.0-inch male (age-group VI) collected at Station 15 on August 12, 1953.

The mean length of pygmy whitefish caught by trawling in Lake Superior was 3.4 inches. The length averaged 2.4 to 4.7 inches at the major collecting areas. The smallest average lengths (2.4 and 2.7 inches) were at Siskiwit Bay and Laughing Fish Point, where 38 to 40 percent of the fish caught were young of the year, and where few large fish were taken. In the Apostle Islands region, in contrast, few young fish were collected; the average length was 4.7 inches.

REPRODUCTION

Age and size at maturity.—All male pygmy whitefish of age-group II or older in collections from Keweenaw Bay, October 2-15, 1953, and from Siskiwit Bay, Isle Royale, September 7, were sexually mature (Table 16). A few I-group males (7 percent) from Keweenaw Bay also were mature.

Relatively few II-group females were mature (3 of 15 in Keweenaw Bay on October 2-15, none of 5 in Siskiwit Bay on September 7, and 3 of 11 on September 30⁵). Of the III-group females, 6 of 10 from Keweenaw Bay and 8 of 11 from Siskiwit Bay were mature and all fish of older age groups were mature in both collections. The age at which 50 percent or more of the pygmy whitefish were mature in Lake Superior was 2 years for males and 3 years for females.

In Weisel and Dillon's (1954) collections from Bull Lake, Montana, all I-group pygmy whitefish were sexually mature. These fish were much larger than the Lake Superior fish, however (p. 185), and were apparently taken from a spawning aggregation, in which immature fish would not be expected. Mature yearling males also occurred in fish from a spawning

⁵ These 11 fish were part of a large collection in which all but 12 were members of age-group I (the twelfth fish belonged to the III-group). Ages were determined by the examination of scales, but no scale measurements were made.

TABLE 16. — *Age at attainment of maturity in pygmy whitefish, Lake Superior, 1953*

Age group	Keweenaw Bay, October 2-15				Isle Royale, September 7						Percentage mature, all fish	
	Males		Females		Males		Females					
	Number of fish	Percentage mature	Number of fish	Percentage mature	Number of fish	Percentage mature	Number of fish	Percentage mature	Males	Females		
I.	61	7	57	0	17	0	10	0	5	0		
II.	14	100	15	20	22	100	5	0	100	15		
III.	5	100	10	60	18	100	11	73	100	67		
IV-VII.	43	100	66	100	1	100	10	100	100	100		

aggregation collected in Lake McDonald, Montana, November 17, 1936.

The data on length at which pygmy whitefish attain sexual maturity (Table 17) are based on 799 fish collected in Keweenaw Bay between August 2 and October 15, 1953, after seasonal development of the gonads had progressed sufficiently to permit accurate determination of maturity. Some males were mature at a total length of 3.0–3.1 inches and some females at 3.8–3.9 inches. Percentage maturity increased progressively with increasing length. Fifty percent or more of the fish were mature at the 3.4- to 3.5-inch class in males and at the 4.2- to 4.3-inch interval for females. All larger fish of each sex were mature.

TABLE 17. — *Length at attainment of maturity in pygmy whitefish, Keweenaw Bay, Lake Superior*

[Stations 9, 11, and 13, August 2–October 15, 1953]

Total length (inches)	Males		Females	
	Number of fish	Percentage mature	Number of fish	Percentage mature
2.2–2.9.....	83	0	87	0
3.0–3.1.....	83	7	55	0
3.2–3.3.....	20	25	18	0
3.4–3.5.....	7	71	6	0
3.6–3.7.....	22	100	9	0
3.8–3.9.....	40	100	20	10
4.0–4.1.....	47	100	16	31
4.2–4.3.....	38	100	14	86
4.4–5.7.....	27	100	207	100

Sex ratio.—Treatment of the sex ratio of different age groups (p. 182) brought out a somewhat erratic variability⁶ but demonstrated an unmistakable trend for males to be scarce or lacking in the older age groups, thus providing an explanation for the predominance of females in most collections. The scarcity of older males in combination with their relatively slow growth led to an unusual relationship between sex ratio and length of pygmy whitefish in Keweenaw Bay in 1953. A summary of data tabulated according to length and sex in Table 15 yields the following:

<i>Total length (inches)</i>	<i>Number of fish</i>	<i>Percentage males</i>
2.0–3.5	422	55
3.6–3.9	115	66
4.0–4.3	134	74
4.4–4.5	59	41
4.6–4.7	59	7
4.8–5.7	151	0

⁶ The unreliability of sex ratios shown by small numbers of fish was emphasized by collections in Siskiwit Bay. In this area 22 of 27 II-group fish collected September 7 were males, but all of 11 II-group fish collected on September 30 at this station were females. This apparent segregation of the sexes probably was not typical, as it was not observed in other collections.

Males were only slightly more numerous than females at 2.0-3.5 inches, reached a predominant position at 4.0-4.3 inches, and dwindled rapidly at 4.6-4.7 inches, the largest length interval in which they were represented at all.

Fecundity.—Maturing eggs were counted in the ovaries of 63 pygmy whitefish collected in Lake Superior in 1953. Egg production ranged from 93 to 597 and averaged 362 (Table 18). The average number of eggs

TABLE 18. — *Production of eggs by pygmy whitefish in Lake Superior, 1953*

[Collection localities and dates were as follows: 57 fish from Keweenaw Bay (Station 11), September 11-October 15; 3 (the smallest in the series, 87-91 millimeters) from Siskiwit Bay (Station 6), September 30; 1 (the largest fish, 149 millimeters) from the Apostle Islands (Station 3), July 29; and 2 (117 and 123 millimeters) off Laughing Fish Point (Station 16), October 21]

Total length (inches)	Average weight ¹ (grams)	Number of fish	Number of eggs		Number of eggs per gram of fish ²	
			Range	Average	Range	Average
3.4-3.9.....	5.9 (1).....	4	93-156	121	.....	26
4.0-4.4.....	8.9 (8).....	9	146-285	235	21-30	27
4.5-4.9.....	13.5 (22).....	26	248-440	344	20-31	26
5.0-5.4.....	17.0 (17).....	20	385-586	457	20-31	26
5.5-5.9.....	21.9 (2).....	4	489-597	531	26-26	26

¹ Numbers of fish weighed (in parentheses) show basis of estimates of numbers of eggs per gram of fish

² Mean of values for individual fish

produced by fish of each $\frac{1}{2}$ -inch length group rose from 121 at 3.4-3.9 inches to 531 at 5.5-5.9 inches. The mean production of eggs per gram of weight ranged between the narrow limits of 20 and 31 and averaged 26 or 27 for all length groups.

In the graphical presentation of egg production (Fig. 5), a line drawn by inspection through the points representing egg production of individual fish has a sigmoid form. The section of steepest rise, between the lengths of 4.3 and 4.7 inches, depicts an average increase of about 160 eggs per $\frac{1}{2}$ -inch increase of length. A decrease in rate to about 100 eggs per $\frac{1}{2}$ -inch of length is indicated by the section of the curve for fish of 5.4 to 5.9 inches. Although the values were rather uniformly distributed about the curve, figures for some individuals were scattered. The greatest deviation for fish of about equal size was shown by two fish (5.3 and 5.4 inches long) which had egg counts of 388 and 586, a difference of 51 percent.

The ovaries of a 117-millimeter female pygmy whitefish collected off Laughing Fish Point on October 21, 1953, contained 78 partly resorbed eggs which had apparently been retained from the previous spawning season. These eggs equalled 36 percent of the average production (Fig. 5) for a fish of its calculated length (108 millimeters) at the approximate time of its failure to expel all of its eggs. Since many eggs may have been resorbed before the time of collection, this fish may not have spawned at all during the previous year. The presence of the partly resorbed eggs in

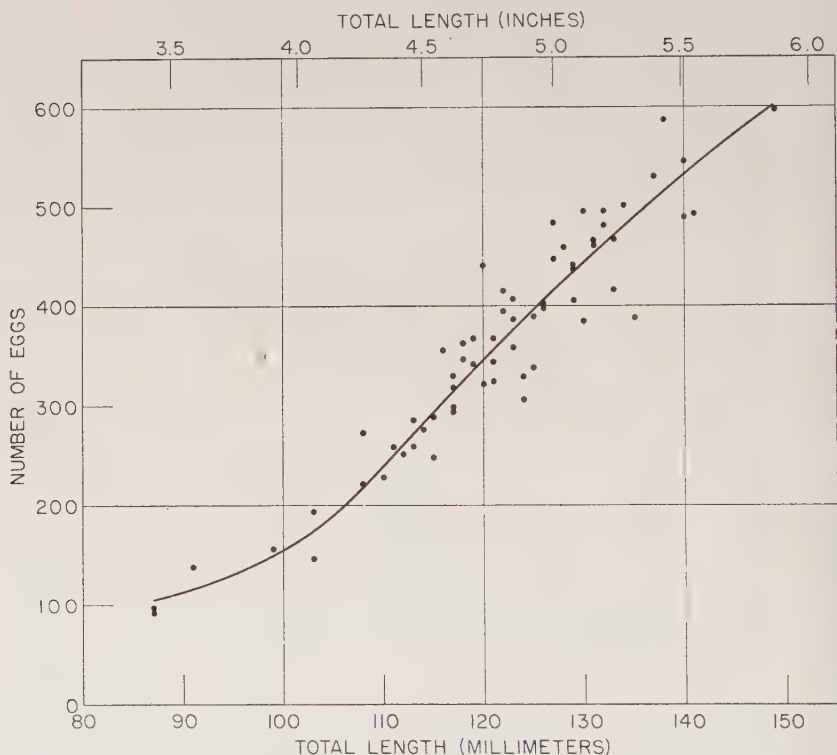


FIGURE 5.—Relationship of length of fish to number of eggs in ovaries of pygmy whitefish. The data are summarized in Table 18.

the ovary did not interfere with production because the 295 new eggs in its ovaries were only 6 percent below the average number for three other fish of the same length.

Residual mature eggs were rarely seen in other ovaries, although one spent female collected January 11, 1954, had 15 such eggs and another had 1.

Time and locality of spawning.—Although no collections of pygmy whitefish were made during the breeding season, spawning in the Laughing Fish Point region undoubtedly occurred during November or December 1953. Ovaries of 2 females of the last fall collection (October 21) were not yet ripe, although they composed 15 percent of the total weight of the fish⁷ and firmly packed the body cavity with large eggs. (Random samples of 25 eggs from each measured in a measuring trough had an average diameter of 2.0 millimeters.) The egg size of the Lake Superior fish was

⁷ The average percentage of the total weight made up by ovaries of 25 mature females collected in Keweenaw Bay on October 15 was also 15.

about the same as that of 2 pygmy whitefish from the spawning run in Bull Lake, Montana. In the Bull Lake fish the average diameter of 11 residual eggs of a nearly spent female was 2.0 millimeters and the average diameter of the eggs of a nearly ripe fish was 2.1 millimeters. Testes of Lake Superior males were not yet ripe in the October collection (not milky in color, as were those of the spawning Bull Lake fish). The gonads of 2 spent, mature males and 2 females collected January 11 appeared to have recovered fully from spawning. The testes were not milky and were smaller than in fish of the October collections. Some of the 15 residual mature eggs found in the ovaries of one of the females were discolored and disfigured; apparently resorption had begun.

In comparison with the November or December spawning of pygmy whitefish in Lake Superior, fish caught in Bull Lake (Weisel and Dillon, 1954) were in breeding condition during the December 26–January 12 period. Kendall (1921) found Alaska fish of this species in spawning condition in one collection in August and in another (from a different locality) in November. Pygmy whitefish caught November 17, 1936, in Glacier National Park, Montana, were in breeding condition and obviously represented a spawning aggregation.

The breeding grounds of the pygmy whitefish in Lake Superior are not known. The capture of young fish in relatively shallow water (13–18 fathoms) at Keweenaw Bay, Point Abbaye, and Siskiwit Bay (Stations 9, 13, and 6) together with the tendency of yearling fish to inhabit the shallower waters of Keweenaw Bay offers some evidence that spawning occurs in shallow water. On the other hand, young fish were caught at 16 to 32 fathoms at Laughing Fish Point (Station 16).

At Bull Lake, Montana, pygmy whitefish in breeding condition were caught in shallow water near the mouth of a tributary stream (Weisel and Dillon, 1954), and the spawning fish from Lake McDonald also were presumably taken in shallow water.

FOOD

Stomach contents were examined from 112 pygmy whitefish 2.4 to 5.9 inches long collected May 7, 1953–January 11, 1954, at 5 stations in Lake Superior. Samples used for food studies were taken at random or comprised all individuals caught in a single drag of the trawl. Because contents of individual stomachs were often too small for satisfactory measurement, a single volume determination (by liquid displacement in a sedimentation tube graduated to 0.01 cubic centimeter) was made for the aggregate of each food item from an entire collection.

Crustacea occurred in 95 percent of the stomachs of pygmy whitefish and composed 77 percent of the total food volume (Table 19). Ostracods and amphipods (principally or entirely *Pontoporeia*), were the chief components, comprising 75 percent of the volume. Ostracods were not found in stomachs from two small collections off Laughing Fish Point but were well represented in fish from other localities. Amphipods occurred in 15 to

TABLE 19. — Percentage frequency of occurrence and (in parentheses) percentage of total volume composed by food items in stomachs of pygmy whitefish in Lake Superior, 1953 [All collection dates were in 1953, except for that of January 11, 1954. Tr indicates volume less than 0.5 percent. Taxonomic groups in footnotes show principal components of higher groups.]

Item	Keweenaw Bay			Siskiwit Bay	Apostle Islands	Laughing Fish Point		Total
	May 7-11	Aug. 2	Oct. 15	Sept. 7	May 30, July 29	Oct. 21	Jan. 11, 1954	
Total length (inches).	3.5-5.4	3.9-5.4	2.7-5.2	2.4-4.3	3.7-5.9	2.9-4.9	4.4-5.0	2.4-5.9
Number of stomachs.	11	7	41	31	15	3	4	112
Crustacea	100 (85)	100 (82)	100 (94)	87 (68)	100 (93)	100 (95)	50 (1)	95 (77)
Cladocera ¹	...	...	215 (tr)	...	...	267 (tr)	...	7 (tr)
Copepoda ⁴	91 (9)	...	12 (tr)	29 (5)	20 (tr)	67 (58)	...	26 (2)
Ostracoda	82 (6)	100 (9)	93 (94)	52 (2)	100 (37)	...	...	76 (31)
Mysidacea ⁵	18 (2)	...	...	...	13 (tr)	...	...	4 (tr)
Amphipoda ⁶	73 (68)	100 (73)	15 (tr)	58 (61)	100 (56)	67 (37)	50 (1)	52 (44)
Hydracarina	...	...	2 (tr)	...	...	...	...	1 (tr)
Insecta	36 (tr)	100 (18)	42 (6)	71 (21)	100 (5)	67 (tr)	50 (1)	62 (9)
Larvae and pupae ⁷ .	36 (tr)	100 (18)	22 (3)	71 (21)	87 (4)	67 (tr)	25 (tr)	52 (8)
Adult ⁸	...	29 (tr)	29 (3)	3 (tr)	33 (1)	...	50 (1)	20 (1)
Pelecypoda ⁹	...	...	...	42 (11)	53 (2)	33 (5)	...	20 (3)
Fish eggs ¹⁰	46 (15)	...	...	...	...	...	100 (98)	8 (11)

¹ *Daphnia* ² *Ephippia* presumed to be of *Daphnia* ³ Both ephippia and adult *Daphnia* ⁴ *Cyclops*, *Mesocyclops*, *Epischura*, *Senecella*, *Diaptomus*, *Limnocalanus* ⁵ *Mysis* ⁶ *Pontoporeia* ⁷ *Cryptochironomus*, *Procladius* ⁸ Hymenoptera, Diptera, Hemiptera, Coleoptera ⁹ *Pisidium conventus* ¹⁰ *Coregonus*

100 percent of the stomachs in the different collections and composed from 1 to 73 percent of the total volume. As many as 285 ostracods or 140 amphipods occurred in a single stomach. Copepods were in 26 percent of the stomachs (2 percent of the total volume) but were usually incidental in the diet of fish more than 3.5 inches long. Cladocera (partly in the form of ephippia, presumably of *Daphnia* or closely related forms) and *Mysis* (which was known to be abundant at several of the collection stations) were unimportant items.

Insects were found in 62 percent of the stomachs and made up 9 percent of the food of pygmy whitefish. Larvae and pupae of aquatic forms (principally Chironomidae) occurred in all collections and in 52 percent of the stomachs but composed only 8 percent of the total volume and did not exceed 21 percent of the food volume in any single collection. Adult insects (undoubtedly taken on or near the lake bottom) were present in 20 percent of the stomachs but made up only 1 percent of the volume. Of the other invertebrates found, larval clams (Sphaeriidae) occurred in 20 percent (3 percent of the volume). Only a single Hydracarina was found.

Fish eggs, presumably coregonine, occurred in the collections of May 7-11 (46-percent frequency of occurrence; 15 percent of the volume) and January 11 (in each of 4 stomachs containing food and comprising 98 percent of the total volume). As many as 30 whole eggs and 29 egg shells were in a single stomach in the January 11 collection. Stomach contents of fish on this date were thus markedly different from those of 3 stomachs collected at the same station on October 21, when copepods and amphipods were the principal food. When available, fish eggs are perhaps important in the diet of pygmy whitefish. In support of this conjecture, Kendall (1921) found from 1 to 18 small salmonid eggs in stomachs of 4 of 5 pygmy whitefish collected at Lake Aleknagik, Alaska, August 2, 1912.

Small quantities of finely divided organic detritus were found in 8 of 21 stomachs that were collected in May. (Possibly this material was equivalent to the "indeterminable mush" reported by Kendall [1921] in stomachs of four pygmy whitefish collected in Lake Aleknagik, Alaska, July 20, 1909.) Sand grains—as many as 27 in a single stomach—were present in 10 of the 112 fish examined.

That copepods are extremely important to small fish was shown by stomach analyses of 5 young individuals collected off Point Abbaye (Station 13) on September 10, 1953, and 12 caught in Siskiwit Bay (Station 6) on September 7 (data not shown in Table 19). Their diet was composed almost entirely of copepods (18 to 144 per stomach); in addition, chironomid larvae and pupae contributed a small proportion of the food of the fish from Point Abbaye and a single cladoceran occurred in stomachs of each of 2 of the 12 fish from Siskiwit Bay.

ASSOCIATED SPECIES

Twelve species or groups of species (the latter not specifically identified) were collected with the pygmy whitefish in Lake Superior. Estimates of the "degree of association" have been made in terms of percentage occurrence in trawl hauls that took pygmy whitefish and percentage occurrence at stations (and on the same dates and depths) at which *Coregonus couleri* was collected (Table 20).

The most common associates of the pygmy whitefish were cottids, which occurred in 87 percent of the hauls and at 88 percent of the stations. The species taken most often was *Cottus cognatus*; *Myoxocephalus quadri-*

TABLE 20. — *Associates of the pygmy whitefish in Lake Superior*

[The ranking of each species or group of species is expressed in terms of its percentage frequency of occurrence in 99 trawl hauls and at 17 stations where pygmy whitefish were taken]

Species	Percentage frequency of occurrence	
	In individual hauls	At stations
Cottidae (<i>Cottus cognatus</i> , <i>C. ricei</i> , <i>Myoxocephalus quadricornis</i>).....	87	88
Ninespine stickleback (<i>Pungitius pungitius</i>).....	81	76
American smelt (<i>Osmerus mordax</i>).....	63	59
Shallowwater cisco (<i>Coregonus artedii</i>).....	36	71
Chubs (<i>Coregonus hoyi</i> , <i>C. reighardi</i> , <i>C. zenithicus</i> , possibly <i>C. kiyi</i>).....	36	65
Lake trout (<i>Salvelinus namaycush</i>).....	57	41
Trout-perch (<i>Percopsis omiscomaycus</i>).....	34	41
Unidentified coregonines (chubs and /or ciscoes).....	34	35
Burbot (<i>Lota lota</i>).....	18	18
Longnose sucker (<i>Catostomus catostomus</i>).....	15	12
White sucker (<i>Catostomus commersoni</i>).....	4	12
Lake whitefish (<i>Coregonus clupeaformis</i>).....	2	6
Chestnut lamprey (<i>Ichthyomyzon castaneus</i>).....	1	6
Yellow perch (<i>Perca flavescens</i>).....	0	6

*cornis*⁸ occurred in numbers only in the deeper waters. The ninespine stickleback was next in importance (81 percent of the hauls; 76 percent of the stations), followed by the smelt, shallowwater cisco (lake herring), and chubs. The latter group was composed of 3 (possibly 4) species. Ciscoes, chubs, and *Coregonus* spp. (unidentified small specimens), when considered as a group, occurred in 84 percent of the hauls and at 88 percent of the stations. Lake trout and trout-perch were other important associates of the pygmy whitefish. Longnose suckers, burbot, lake whitefish, white suckers, chestnut lampreys, and yellow perch were much less common, occurring only in occasional trawl hauls or collection stations. Absent from the list was the round whitefish, closest relative of the pygmy whitefish in Lake Superior (chiefly a resident of shallower waters). With the exception of four young (1.5 to 1.6 inches in total length) caught in the Apostle Island region on July 29, 1953, and a 3.5-inch yearling caught west of Grand Marais, Michigan, on June 14, 1953, *Coregonus cylindraceus* was not taken by trawling in Lake Superior. The Cyprinidae, Percidae, and Centrarchidae, dominant groups of American fishes, are notable for their scarcity or absence in the deep cold waters of Lake Superior where *C. couleri* lives.

⁸ The fourhorn sculpin, better known to most North American ichthyologists as the deepwater sculpin, *Trigloopsis thompsoni* Girard, is chiefly a circumpolar marine fish. In certain large lakes in northern Europe and North America there occur isolated populations that are presumably relicts of independent invasions from the sea near the close of the Pleistocene. This freshwater ecotype contrasts with the saltwater fish in the smaller size, the reduction in number and development of ossified plates on the body, and the weakening or loss of the four rugose ridges or knobs on the top of the head (Berg and Popov, 1932; Berg, 1949). A number of subspecies have been established on variations, mainly in the characters mentioned (Berg and Popov, 1932). Whether or not any of these have a genetic basis is a matter for conjecture. The populations from Lake Onega, Russia, and the Great Lakes are strikingly similar. Until the nature of the variations is more clearly understood we concur with Vladkov (1933) in adopting the binomial designation for all populations of *Myoxocephalus quadricornis* (Linnaeus).

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TWO-YEAR CREEL CENSUS OF THE LITTLE SALMON RIVER, IDAHO

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ABSTRACT

The use of stratified periods, random sampling days and voluntary information provided by the participating anglers provided a method of creel census which required a minimum of working days and still allowed constant highway travel in the working area to flow uninterrupted. A maximum of two men on 24 days was used to census a season total of nearly 7,000 anglers on 24 miles of the stream.

In 1952, of 1,107 anglers interviewed 940 (84.9 percent) returned catch data. In 1953 1,140 anglers were interviewed and 1,042 of these (91.4 percent) responded.

Total estimated catch was 47,772 in 1952 and 46,997 in 1953. Hatchery-reared rainbow trout comprised 2,223 of the 1952 catch and 4,867 of the catch in 1953. Recovery of these planted fish amounted to 37.1 percent of 6,000 released in 1952 and 57.9 percent of 8,400 in 1953. Anglers retained an estimated 58.5 percent of the total catch in 1952 and 72.2 percent in 1953.

Statistical analysis proved the estimate of the total reported catch to be within the limits desired for management purposes.

INTRODUCTION

The Little Salmon River watershed contains approximately 582 square miles. The main stem of the drainage flows in a northerly direction, entering the Salmon River at Riggins, Idaho. The principal north-south route of travel in Idaho, U. S. Highway 95, runs adjacent to the lower 35 miles of the stream. The entire drainage, except the lower 24 miles of the main stream, for years has been included in the general fishing season, June 4 to October 31. The lower 24 miles has remained open to the taking of all species of fish during the period April 15 to October 31. In the past 15 years, cabin accommodations for fishermen and tourists have been constructed in nine locations on the lower 20 miles of the stream. A 2-year creel census of the lower part of the stream was prompted by the increased fishing pressure the past few years, the 50 days of additional fishing, and reports of decreased success.

METHOD OF CENSUS

Ordinary methods of creel census were not applicable on this stream. Heavy traffic on Highway 95 prevented stopping automobiles to check creels as the anglers left the fishing area. Also, the lack of available personnel to make daily observations made some method of sampling necessary.

The 200-day fishing season was stratified into eight periods of 25 days each. One Sunday, one Saturday, and one week day from each of the 25-day periods were selected at random as the representative census days for that period. The 24-mile census area was divided into six sections of approximately 4 miles each. Self-addressed, stamped postcards with blank spaces for the date, the number of fish kept, the number of fish released, and the hours fished, were prepared. All postcards were numbered. Record sheets to be used by the census-takers were mimeographed to include the date, the name of the census-taker, the card number, the car license number of the angler, name and address of the angler, stream section, and catch.

The area was covered each census day by automobile. One or two census-takers were used, depending upon the anticipated number of anglers. Census-takers began the day early enough to contact the first anglers to appear and continued throughout the day until no new fishermen appeared or until darkness ended the fishing day. Each angler was interviewed by the census-takers, and during the interview the angler was given a postcard. The purpose of the census was briefly explained with emphasis on the return of the card regardless of the fishing success. Fishing licenses were not checked unless offered for inspection. The anglers were informed that the census card was to include only the results of fishing on the date of interview. They were requested to mail the card at their earliest convenience. During the interview, each creel was inspected and the catch recorded by number and species. To avoid repeated contact with the same anglers, each one was listed under the license number of the automobile in which he was traveling. The section of the stream in which the angler was interviewed was recorded. The entire 24-mile area was covered a minimum of six times each census day. This same procedure was followed both years.

A few cards returned the first year included the total fish caught over a period of more than one day without showing a breakdown of the daily catch. As a result, the census cards used in 1953 were improved to include requests that the angler report his catch only for the day he was interviewed and that the postcard be mailed even though no fish were caught (Fig. 1).

To test the psychological effect of asking the names and addresses of anglers on the voluntary return of the cards, no names were requested on 3 of the first 6 census days in 1952. Names were taken on the other 3 days. After sufficient time had elapsed to insure the voluntary return of the cards, a comparison of the two groups showed that there was a slightly higher percentage return from the group whose names had been recorded.

At the beginning of the 1952 census, fishermen were recorded by the section of the stream in which they were fishing at the time of the interview to indicate fishing pressure in the various sections. However, so many anglers appeared in all six sections during one fishing day that analysis of fishing pressure by sections was soon abandoned.

At intervals throughout the season, questionnaires were mailed to those persons who had failed to return the original census card voluntarily. Included in the questionnaire were several reasons for the failure to return the postcard. Also included was a request for fishing information regarding the success on the day of the interview. A self-addressed envelope was enclosed for the return of the questionnaire. With the use of the original census postcard, the questionnaire mailed to the non-responsive angler, and the information gathered directly by the census-takers from anglers who had completed their fishing day, three distinct categories of census information were established. To distinguish among these categories,

No. 1228	Little Salmon River		
Report catch for _____, 1953, <i>only</i> .			
Please fill out and return card even though <i>no</i> fish are caught.			
<i>CATCH:</i>			
	<i>Trout</i>	<i>Salmon</i>	<i>Steelhead</i>
Number caught and kept	_____	_____	_____
Number caught and released	_____	_____	_____
Total Number of Hours Fished	_____		
Remarks or additional information	_____		

FIGURE 1.—Self-addressed, stamped postcard used for voluntary return.

information from the original postcard will be termed "postcard", returns from the mailed questionnaire "questionnaire", and data gathered directly by census-takers from anglers who had completed their fishing day "interview". In 1952, a total return of census information was received from 940 of 1,107 anglers contacted. In 1953, this return was increased to a response of 1,042 from 1,140 contacts (Table 1).

METHOD OF CALCULATING INTENSITY AND SUCCESS

Fishing intensity for the entire season was estimated by multiplying the average number of anglers interviewed on the eight Sundays, Saturdays, and week days by the total number of Sundays, Saturdays, and week days within the 200-day season. Total hours fished, fish caught, and fish kept were estimated in the same manner with adjustments made for those few persons who failed to return census information. Opening day (April 15), Memorial Day, and Labor Day were treated as Saturdays, and July 4 was treated as a Sunday. The 1952 season was composed of 29 Sundays, 31

TABLE 1.—Summary of creel-census returns by method

Type of return	1952	1953
Postcard		
Number of returns.....	612	734
Total hours fished.....	2,438	2,557
Total fish kept.....	3,194	3,910
Fish per hour.....	1.31	1.53
Questionnaire		
Number of returns.....	252	257
Total hours fished.....	988	947
Total fish kept.....	991	1,167
Fish per hour.....	1.00	1.23
Interview		
Number of returns.....	75	51
Total hours fished.....	153	85
Total fish kept.....	164	137
Fish per hour.....	1.07	1.61
Total		
Number of interviews.....	1,107	1,140
Total returns.....	940	1,042
Percentage returns.....	84.9	91.4

Saturdays, and 140 week days, while 29 Sundays, 30 Saturdays, and 141 week days appeared in 1953. The total number of anglers who fished the 24 miles of census area was estimated to be 6,555 in 1952 and 6,991 in 1953. The estimated total number of fish caught dropped from 47,772 in 1952 to 46,997 in 1953. However, the number of fish kept increased from 27,947 in 1952 to 33,914 in 1953. More small fish were retained by the anglers in 1953. In 1952, 16.7 percent of the fish kept by the fishermen were caught during the first 50 days of fishing. Fish kept during the same period in 1953 represented 19.6 percent of the season's total (Table 2).

SPECIES COMPOSITION OF THE CATCH

Inspection of the creel during the interview of each angler allowed the census-takers to observe 21.7 percent of the fish kept on census days in 1952 and 22.2 percent in 1953. Rainbow trout, *Salmo gairdneri*, composed 96.3 percent of the observed fish kept in 1952 and 95.7 percent in 1953. Other species included: eastern brook trout, *Salvelinus fontinalis*; cut-throat trout, *Salmo clarki*; dolly varden, *Salvelinus malma*; mountain whitefish, *Prosopium williamsoni*; chinook salmon, *Oncorhynchus tshawytscha*; and steelhead trout.

HATCHERY FISH IN THE CATCH

During the 1952 season, a total of 6,000 rainbow trout of catchable-size were released in the 24-mile census area, 1,200 on each of five planting dates. The six sections received 200 fish each from each planting. The

TABLE 2.—*Summary of Little Salmon River creel census*

Item	Fishermen interviewed		Calculated hours fished		Calculated fish caught		Calculated fish kept	
	1952	1953	1952	1953	1952	1953	1952	1953
Census total								
Sunday.....	609	590	2,410	2,159	4,771	4,060	2,895	2,886
Saturday.....	326	353	1,330	1,154	2,421	2,778	1,428	1,925
Week day.....	172	197	478	604	1,095	1,238	703	922
Census average								
Sunday.....	76	74	301	270	596	508	362	361
Saturday.....	41	44	141	144	302	347	179	241
Week day.....	22	25	60	75	137	155	85	115
Season total								
Sunday.....	2,204	2,146	8,729	7,830	17,284	14,732	10,498	10,469
Saturday.....	1,271	1,320	4,371	4,335	9,362	10,410	5,549	7,230
Week day.....	3,080	3,525	8,400	10,645	19,180	21,855	11,900	16,215
Season totals.....	6,555	6,991	21,500	22,810	47,772	46,997	27,947	33,914
Fish per hour.....	.....	.....	.....	.....	2.22	2.06	1.31	1.49

different lots were marked with a different single fin clip to identify them in the catch as the season progressed.

From the percentage of marked fish observed in the creel on each census day an estimate was made of the total catch of hatchery fish on that day. The resulting figures on the total take of hatchery fish on each census day were then employed to calculate estimates of the total recapture from the various plantings in the several census periods. Thus, the 37.1 percent total calculated harvest of hatchery-reared rainbow trout numbered 2,223 of 6,000 released in 1952 (Table 3).

The 1953 planting schedule was altered to include 1,200 additional marked fish on two of the planting dates, that is, plants of 2,400 fish were made on June 20 and July 28. With this 40-percent increase in the number of fish released the rate of recapture rose to 57.9 percent as contrasted to only 37.1 percent the previous year. A total of 4,867 fish were caught from 8,400 released in 1953. This rate of recapture could not have resulted from carry-over of fish planted in 1952 (the same marks were used in 1952 and 1953). Only four marked fish (fish of the 1952 plantings) were observed in the catch during the first 6 census days prior to the first plantings of marked fish in 1953. The possible winter carry-over of marked fish released in 1952, therefore, was given no consideration in the calculation of the 57.9-percent return of fish released in 1953.

STATISTICAL ANALYSIS

After the completion of the 1953 investigation, the variation in the daily reported catch for the 2 years was analyzed by methods described by Embury (1954). A highly significant variation occurred between the days of the week. Differences among the eight periods were also highly signifi-

Sampling period and census day	Days in period		Recoveries in sample by mark and release date										Total recoveries in sample		Percentage planted fish in total sample		Calculated number of fish caught	
	1952	1953	Adipose June 6	Left ventral June 20		Right pectoral July 16		Right ventral July 28	Left pectoral Aug 11		1952	1953	1952	1953	1952	1953	1952	1953
				1952	1953	1952	1953		1952	1953								
June 4—June 28																		
Sunday.....	3	4	11	7	13	15	..	..	..	..	24	22	16.8	56.4	79	90		
Saturday.....	4	4	4	25	..	..	..	..	..	..	4	25	22.1	59.5	14	70		
Week day.....	18	17	1	1	..	..	..	..	..	..	1	1	4.3	5.6	2	3		
June 29—July 23																		
Sunday.....	5	4	3	4	3	11	..	..	..	..	26	28	23.6	18.3	153	110		
Saturday.....	3	2	2	5	1	9	..	..	..	..	9	24	11.1	28.2	41	163		
Week day.....	17	19	..	6	..	13	..	..	..	..	..	19	..	32.2	0	91		
July 24—Aug. 17																		
Sunday.....	4	4	1	..	..	2	5	8	12	10	24	22	21.4	27.2	83	196		
Saturday.....	4	4	1	..	..	4	4	7	18	..	14	26	18.2	29.2	58	136		
Week day.....	17	17	..	..	3	..	3	8	..	..	14	14	19.2	38.9	45	61		
Aug. 18—Sept. 11																		
Sunday.....	3	3	1	..	..	1	1	2	2	5	8	13	6.6	26.0	39	57		
Saturday.....	4	4	..	..	..	1	..	8	..	..	1	9	5.9	13.6	9	50		
Week day.....	18	18	..	..	..	..	..	2	2	1	2	3	10.5	9.7	17	13		
Sept. 12—Oct. 6																		
Sunday.....	4	4	..	..	1	..	..	1	..	2	2	2	7.7	4.9	15	13		
Saturday.....	4	4	..	..	..	..	..	1	..	..	..	..	..	..	0	0		
Week day.....	17	17	..	..	..	..	..	..	..	2	..	3	..	14.3	0	8		
Oct. 7—Oct. 31																		
Sunday.....	3	3	1	..	1	..	..	2	..	..	2	2	3.1	5.0	4	5		
Saturday.....	3	4	..	..	..	..	1	..	1	..	1	1	3.2	7.7	4	4		
Week day.....	19	18	..	..	..	..	..	..	..	..	..	..	..	..	0	0		
Total																		
Sunday.....															373	480		
Saturday.....															126	423		
Week day.....															64	176		
Average																		
Sunday.....															62.2	80.0		
Saturday.....															21.0	70.5		
Week day.....															10.7	29.3		
Season total																		
Sunday.....															1,008	1,296		
Saturday.....															353	1,227		
Sunday.....															862	2,344		
Week day.....																		
Total															2,223	4,867		
Percentage return planted fish.....															37.1	57.9		

cant. The difference between years was not significant. The best estimate for the total reported catch for each year was 39,100 fish. Confidence limits corresponding to 95-percent probability were 30,200 and 48,000.

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AGE, GROWTH, AND PRODUCTION OF THE LAKE STURGEON (*ACIPENSER FULVESCENS*) IN THE LAKE WINNEBAGO REGION, WISCONSIN

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ABSTRACT

Lake sturgeon populations, markedly reduced throughout most of their range, now support commercial or sport fisheries in few regions. A sport fishery in the Lake Winnebago area annually attracts approximately 2,000 spearkers who take from about 400 to more than 2,800 fish. When spearing conditions are favorable more persons participate in the sport and enjoy a greater rate of success. The estimated catch of 2,828 lake sturgeon speared in 1953, weighing approximately 100,000 pounds, represented the largest catch on record. This annual yield of lake sturgeon is exceeded in North America only by commercial fisheries for white and green sturgeon in the States of Washington and Oregon.

Lengths of lake sturgeon speared ranged from 30 to 79 inches; fish from 37 to 40 inches long were most abundant in the catch.

Age determinations were accomplished by examining transverse sections of the marginal ray of the pectoral fin. Age-groups from 0 to LXXXII were represented in collections made in the Lake Winnebago area with age-groups XV to XXX most numerous. Growth in length is rather rapid during the first few years with the fish attaining the former legal size of 30 inches in about 7 years. A 40-inch sturgeon would be approximately 13 years old and a 50-inch fish, 20 years. No difference was noted in growth of the sexes.

The length-weight relationship of lake sturgeon in the Lake Winnebago area was computed to be: $\log W = -4.17096 + 3.30367 \log L$, where W is weight in pounds and L is total length in inches.

Female lake sturgeon live longer and thus grow to larger sizes than do the males. Females made up 96 percent of the total catch of fish over 60 inches long.

Tendipedid larvae were the most important food item taken by the lake sturgeon in Lake Winnebago. In the smaller lakes, mayflies and aquatic sow bugs were also taken frequently.

The waters of the Lake Winnebago region, Lakes Winnebago and Butte des Morts on the Fox River and Lakes Poygan and Winneconne on the Wolf River, comprise an unobstructed system of four river lakes in the east-central part of Wisconsin. The Fox River joins the Wolf River in Lake Butte des Morts, thence flows into Lake Winnebago enroute to Green Bay, Lake Michigan.

Lake Winnebago, the largest body of water in the 156,000-acre system, has an area of 137,708 acres. The maximum depth is about 21 feet and the average depth, approximately 15 feet (Juday, 1914). The smaller Lakes Poygan, Winneconne, and Butte des Morts have areas of 10,992, 3,264, and 4,505 acres, respectively. The depths of Lakes Poygan, Winneconne, and Butte des Morts are similar. The maximum depths, usually

located in the river channels, do not exceed 11 feet. The average depths are considerably less. All four bodies of water have many characteristics common to eutrophic lakes.

SPORT FISHERY FOR LAKE STURGEON

Lake sturgeon populations, markedly reduced throughout most of their geographical range, now support commercial or sport fisheries in few regions. No sport fishery for lake sturgeon in any area of the United States or Canada is known to surpass that now in existence in Lake Winnebago and its associated waters. With the exception of a limited and relatively unproductive set-line season in the fall, the fishery for lake sturgeon in the Lake Winnebago region consists of spearing through the ice during February. This type of sport fishery for lake sturgeon is unique to Wisconsin, except for a limited fishery in three lakes of Michigan: Black Lake, Mullett Lake and Burt Lake, in the Cheboygan River drainage (Williams, 1951).

Lake sturgeon are speared through a hole in the ice inside a portable shanty. The size of the hole depends on the size of the shanty, but it is usually about 3 feet wide and 5 feet long. Pieces of broken pottery and mussel shells, shelled corn, paper plates, pieces of tin or tinfoil and a variety of other materials are generally scattered over the bottom to increase visibility. Decoys of various shapes, colors, and materials including ears of corn, wooden toy airplanes, oranges, and skillfully carved and painted replicas of fish are often suspended through the hole. The objects are intended to attract lake sturgeon into better position for spearing. The spear is constructed with a handle that detaches, enabling the fisherman to play the speared fish on a line.

The spearing of lake sturgeon, permitted in Lake Winnebago for many years, was not extended to Lakes Poygan, Winneconne, and Butte des Morts until 1952. A sudden influx of fishermen accompanied the extension of the fishery. Fishermen spearing lake sturgeon increased from 1,427 in 1951, when only Lake Winnebago was open, to 3,074 in 1953. The number of shanties in operation also increased. In 1952, a total of approximately 200 shanties were erected on Lakes Poygan, Winneconne, and Butte des Morts.¹ The shanties on these lakes augmented to 315 in 1953; and in the same year approximately 750 shanties were used on Lake Winnebago.

The sturgeon spearkers on Lakes Poygan, Winneconne and Butte des Morts were largely new fishermen using this expanded fishery. Fishermen are required to identify their shanties with the owner's name and address. By this means of identification, it was determined that the migration of a small number of Lake Winnebago fishermen to Lakes Poygan, Winneconne, and Butte des Morts during the first open season of 1952 was temporary and did not contribute to the fishery in these lakes thereafter.

¹ All data concerning Lakes Poygan, Winneconne, and Butte des Morts have been combined, because Lakes Poygan and Winneconne are now practically one body of water, and data from Lake Butte des Morts are limited.

HARVEST OF LAKE STURGEON BY SPEARING

A total of three lake sturgeon may be taken by means of spear or set line during a fishing season.² The limit is enforced by a regulation requiring the immediate attachment of a special tag to the tail of each lake sturgeon caught. No more than three such tags, costing \$1 each, may be issued to a person during one season.

Upon the close of each lake sturgeon season, fishermen purchasing tags are required to file a report of their success on creel-census cards which are distributed at the time of tag purchase. The size of the fish speared is also reported. Although only a portion of these cards are returned, the estimated catch has been computed for all years for which records are available (Table 1). These estimates assume that the same percentage of successful and unsuccessful fishermen reported. Also, differences in the rate of success between the small lakes and Lake Winnebago have been disregarded because the calculation of separate catch estimates for each lake was not feasible due to insufficient data. These methods are similar to those used by Schneberger and Woodbury (1946) in an earlier report of the lake sturgeon catch in Lake Winnebago.

Favorable fishing conditions lead more persons to participate in spearing lake sturgeon, and also produce higher catches as occurred in 1948, 1950, and 1953. In some years, ice forms late in the season and does not permit safe travel by automobile to points very far from shore. Also, winter thaws render ice unsafe, sometimes abruptly terminating spearing operations. Heavy snowfall with high winds discourage spearers from attempting to reach their shanties which may be as much as 4 miles from the nearest shore. Additional adverse effects of unfavorable weather appear when heavy fall rains or midwinter thaws cause high turbidity in the water due to runoff from heavy clay soils.

The catch of 2,828 lake sturgeon in 1953 was an all-time high. This was the first good season after the smaller lakes were added to the waters open for spearing. The previous record catch was 1,735 fish speared in 1948.

Separate analyses of the 1953 creel-census data for Lake Winnebago and the smaller lakes indicate the rate of success (the average number of lake sturgeon speared per man) to be the lower in Lake Winnebago. The average number of fish speared per man during 1953 in the small lakes (computed from 175 returned creel-census cards) was 1.14, while that calculated for Lake Winnebago (from 536 cards) was 0.83. This higher success rate may be accounted for in part by the better spearing conditions that prevail in the smaller lakes when compared with Lake Winnebago. Most spearing in Lake Poygan, Butte des Morts, and Winneconne is done in water less than 10 feet deep, whereas in Winnebago much of the spearing occurs in water between 10 and 18 feet deep, depending on visibility.

It is evident that a relatively high correlation exists between the number of persons spearing lake sturgeon and the reported rate of success in

² The season limit of five fish was reduced to three in the 1954 season.

TABLE 1. — *Fishing pressure, estimated catches, and the estimated weight of lake sturgeon speared in Lake Winnebago during the years 1941-1943 and 1947-1951, and in Lakes Winnebago, Poygan, Winneconne, and Butte des Morts for the period 1952-1953*

Item	Lake Winnebago only										Lake Winnebago and other lakes	
	1941	1942	1943	1947	1948	1949	1950	1951	1952	1953		
Number of persons purchasing tags.....	829	719	449	1,275	2,471	1,661	2,019	1,427	1,839	3,074		
Number of creel-census cards returned.....	162	77	290	228	618	471	298	256	450	710		
Number of sturgeon reported speared.....	154	50	154	90	434	109	117	109	200	642		
Average number of sturgeon per man.....	0.95	0.65	0.53	0.39	0.70	0.23	0.39	0.43	0.44	0.92		
Estimated number of sturgeon in total catch...	788	467	283	503	1,735	384	793	608	817	2,828		
Estimated weight of total catch (pounds).....	33,000	19,500	12,000	21,000	72,500	16,000	33,000	25,500	30,000	100,000		

Lake Winnebago. In years of higher rates of success, more fishermen participate in the fishery than in years when the success is lower. Schnberger and Woodbury (1946) attributed the decline in persons spearing lake sturgeon from 1941 to 1943 to the general labor shortage and limited free time to fish, but in most years fishing conditions govern the size and success of the fishery.

The total weight of the annual catches prior to 1952 has been estimated from the average weight of 41.8 pounds for 756 lake sturgeon collected from Lake Winnebago. For 1952 and 1953, the weight was estimated, in part, from the catch in Lake Winnebago and, in part, from that in Lakes Poygan, Winneconne and Butte des Morts, where 491 lake sturgeon averaged 24.7 pounds.

The 1953 anglers' catch of approximately 100,000 pounds of lake sturgeon from the Lake Winnebago area exceeds the annual catch of every commercial fishery for this species in the United States and Canada. In 1951, only 38,401 pounds of sturgeon were reported from Canadian and United States waters of all of the Great Lakes and certain other waters, with Lake Erie producing over 20,000 pounds of the total (Anderson and Peterson, 1954). A declining commercial fishery in Lake St. Francis on the St. Lawrence River in Quebec yielded an average of 13,820 pounds annually from 1933 to 1941 (Cuerrier and Roussow, 1951). Closed since 1948, the Nelson and Churchill Rivers in Manitoba were reopened to commercial fishing in 1953 with an established maximum annual yield of 25,000 pounds of lake sturgeon from each river.

The commercial fishery for the white sturgeon (*A. transmontanus*) and the green sturgeon (*A. medirostris*) produced 295,400 pounds in 1951 with the states of Washington and Oregon nearly equally dividing this total (Anderson and Peterson, 1954). However, some authors have expressed their concern over the possible extermination of these species due to the lack of large fish in the present-day fishery (Clemens and Wilby, 1946).

LENGTH DISTRIBUTION OF THE CATCH

The lengths of speared lake sturgeon extended from the minimum legal length of 30 inches to 79 inches which is the largest fish speared on record from these waters.³ Small lake sturgeon accounted for a greater percentage of the catch in Lakes Poygan, Winneconne, and Butte des Morts than in Lake Winnebago (Fig. 1). Lake sturgeon over 60 inches long were relatively abundant in the catch from Lake Winnebago compared with the catch from the smaller lakes. Fishermen are of the opinion that few small fish are present in Lake Winnebago since they are seldom seen; some small lake sturgeon are caught, nevertheless in rough-fish-removal operations by state crews.

The length-frequency distribution of lake sturgeon speared in Lakes

³ The minimum legal size limit was increased to 40 inches in September 1954.

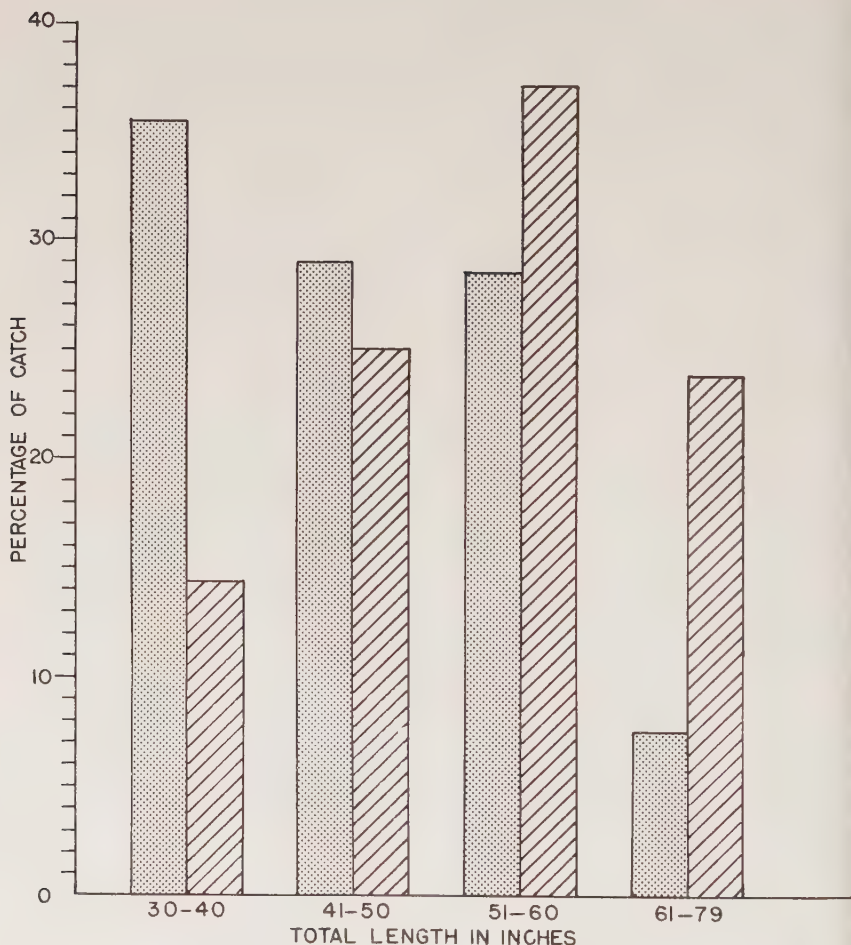


FIGURE 1.—Comparison of length-frequencies of lake sturgeon speared in Lake Winnebago (cross-hatched bars) with those taken in Lakes Poygan, Winneconne and Butte des Morts (dotted bars).

Poygan, Winneconne, and Butte des Morts was bimodal (Table 2). Two principal peaks of the length distribution occurred at 37 inches and 53–54 inches. Fish from 37 to 40 inches long were most abundant in the catch.

In Lake Winnebago, the length-frequency distribution of 178 lake sturgeon measured by trained personnel agrees closely with that drawn from the measurements of 682 lake sturgeon reported by spearers. Fish are most numerous at about 60 inches, and at a somewhat larger size than the mode between 53 and 54 inches for Lakes Poygan, Winneconne and Butte des Morts.

TABLE 2. — Length frequency of lake sturgeon taken by spearing in the Lake Winnebago area during the seasons of 1952, 1953, 1954

Total length in (inches)	Lake Winnebago		Lake Poygan, Winneconne and Butte des Morts
	Reported on census cards	Measured in field	Measured in field
28.0-29.9	...	...	2
30.0-31.9	3	...	9
32.0-33.9	9	...	25
34.0-35.9	17	4	49
36.0-37.9	28	4	74
38.0-39.9	29	4	54
40.0-41.9	29	3	67
42.0-43.9	45	4	43
44.0-45.9	34	6	44
46.0-47.9	29	8	35
48.0-49.9	41	10	32
50.0-51.9	31	9	43
52.0-53.9	44	7	50
54.0-55.9	40	9	52
56.0-57.9	48	18	32
58.0-59.9	49	17	25
60.0-61.9	69	23	26
62.0-63.9	40	19	21
64.0-65.9	37	13	9
66.0-67.9	30	9	6
68.0-69.9	11	3	4
70.0-71.9	10	4	2
72.0-73.9	5	2	...
74.0-75.9	2	...	...
76.0-77.9	1	1	...
78.0-79.9	1	1	...
Total	682	178	704

In Lake St. Francis on the St. Lawrence River in Quebec, the most numerous size group of 337 lake sturgeon taken by means of gill nets of 8-inch mesh (stretch measure) was between 27 and 28 inches fork length which is approximately 30 inches total length (Cuerrier and Roussow, 1951). The average size of the lake sturgeon in this fishery is considerably less than that for Lakes Poygan, Winneconne and Butte des Morts.

DETERMINATION OF AGE

The use of bony structures for the determination of age in fishes has long been widely accepted. Appleget and Smith (1951) and Chugunov (1926), among others, have reviewed various methods of aging fish by bones. Cuerrier (1951) adequately summarized the history of age-determination methods by bones in the Acipenseridae.

In the present study, the marginal ray of the pectoral fin was used in the determination of age. Transverse sections were cut from the dried bone with a very fine-toothed jeweler's saw as described by Cuerrier (1951). In order to produce a higher degree of differentiation between the translucent and opaque zones, the cut sections were immersed in a 50-

percent alcohol bath immediately prior to examination. Age determinations were made with a wide-field microscope with low magnification or on a projection machine. The alcohol solution had no apparent deleterious effects on the sections, regardless of the number of times the same section was examined. Glycerine and xylol were also used for differentiation, but neither was as satisfactory as alcohol. Glycerin penetrates slowly and has to be completely removed through alcohol baths in order to prevent permanent clearing. Xylol penetrates too rapidly, especially on thin sections, and often causes headaches.

VALIDITY OF AGE DETERMINATION

Cuerrier (1951) has summarized the results of studies designed to validate the age determination of different species of sturgeons from transverse sections of pectoral fin rays. The translucent zones in sections of fin bones appear to be valid year marks in the material collected from the Lake Winnebago area lake sturgeon (Fig. 2, 3, and 4). A lake sturgeon 7.1 inches in length collected October 14, 1953, had no recognizable annuli on the fin-bone section. Another small fish, 15.4 inches long, taken January 28, 1953, showed one annulus and a marginal translucent zone indicating two complete seasons of growth (Fig. 2). Additional increases in length of the lake sturgeon were accompanied by increases in the number of annuli noted on fin bone sections (Fig. 3 and 4).

The correlation between the length- and the age-frequency distributions for lake sturgeon speared in Lakes Poygan, Winneconne, and Butte des Morts provides additional evidence that age determinations of the material in this study have been accurate (Table 2 and Fig. 5). The age-frequency distribution for 697 lake sturgeon is a bimodal curve, with peaks occurring at 15 years and 24 years. The age-frequency curve is acutely depressed between the two modes. The average length for lake sturgeon 15 years old is approximately 43 inches, and that for 24-year-old fish is approximately 53 inches. Thus the average size of the fish in these dominant year classes corresponds fairly well with the observed peaks in abundance in the length-frequency curve.

GROWTH OF LAKE STURGEON

Age was assessed for 966 lake sturgeon caught from 1951 to 1954 (Table 3). Age groups ranged from I to LXXXII (82), but the numbers in the young and old groups were relatively low.⁴

Rates of growth have been determined on the basis of average lengths for given ages and not by the method of back-calculation. Variations in the shape and diameter measurements of transverse sections of the

⁴ Under the commonly accepted system of age designation (Hile, 1948) age-group I would be properly called age-group 0 since these fish are young-of-the-year collected in October and November. However, all other fin bones were collected in January and February and hence were credited with a "virtual" annulus at the margin. To keep all age designations comparable the 0-group fish were given their virtual annulus a little in advance of the usual date of January 1.

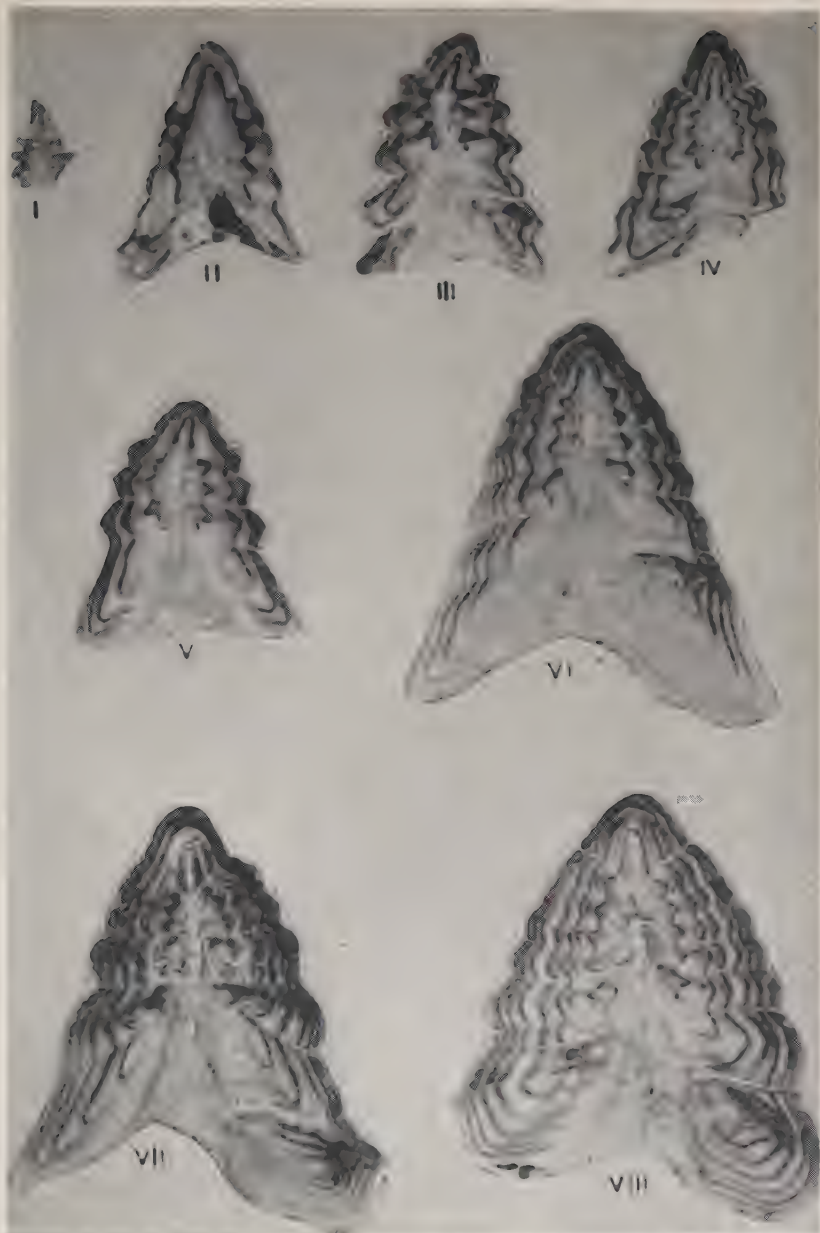


FIGURE 2.—Transverse sections of the marginal ray of the pectoral fins of lake sturgeon of various ages showing year marks. Dark lines represent translucent zones laid down during winter growth period. All fish but the I-group individual (taken in October) were caught in January or February and hence have a "virtual" annulus credited at the edge of the section (see also footnote 4.) I—7.1 inches, 0.04 pounds; II—15.4 inches, 0.52 pound; III—18.9 inches, 1.0 pound; IV—21.7 inches, 1.8 pounds; V—25.3 inches, 2.8 pounds; VI—34.0 inches, 9.3 pounds; VII—34.0 inches, 9.5 pounds; VIII—36.0 inches, 11.0 pounds.

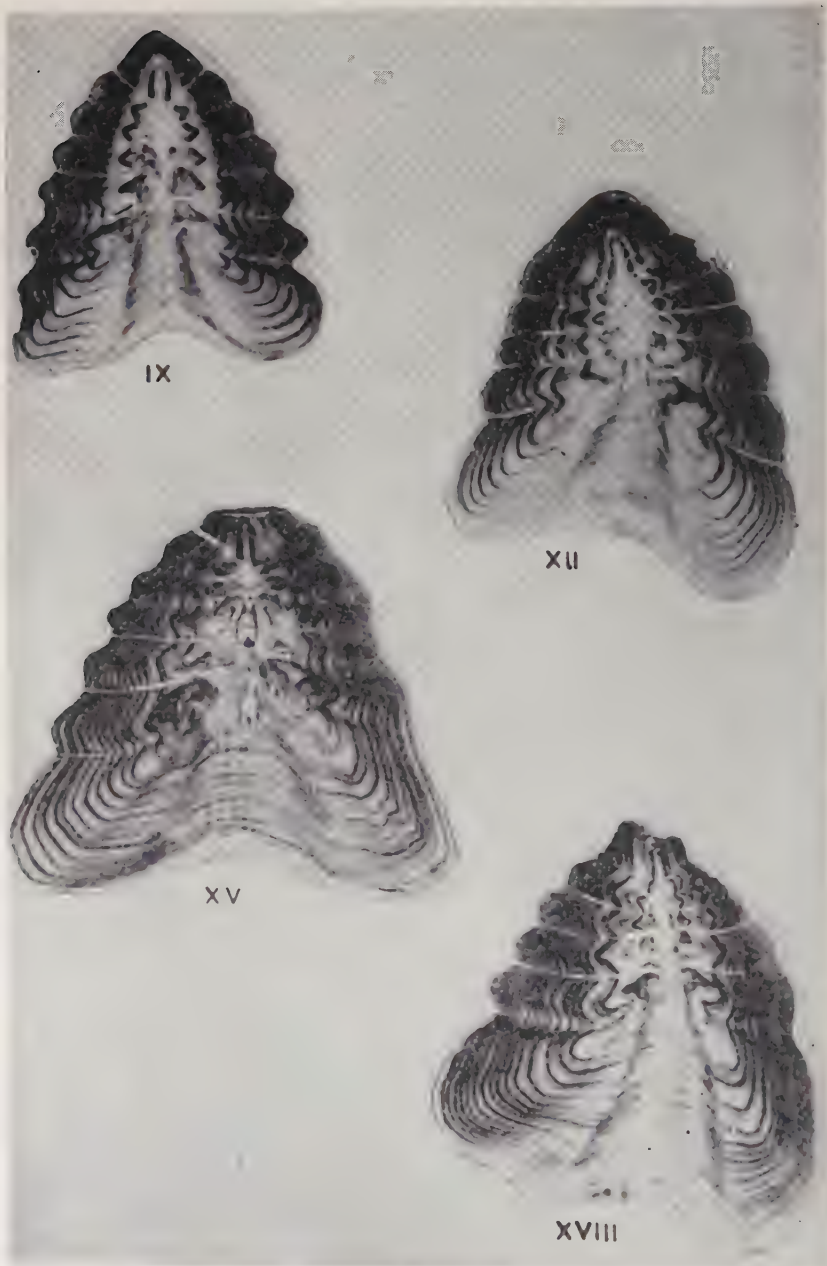


FIGURE 3.—Transverse sections of marginal ray of the pectoral fin of lake sturgeon of various ages showing year marks. All fish were caught in January or February and hence have a "virtual" annulus credited at the edge of the section. IX—39.0 inches, 11.0 pounds; XII—46.5 inches, 21 pounds; XV—49 inches, 35 pounds. XVIII—53 inches, 38 pounds



FIGURE 4.—Transverse sections of marginal ray of the pectoral fin of lake sturgeon of two ages showing year marks. All fish were caught in January or February and hence have a "virtual" annulus credited at the edge of the section. XXV—59 inches, 63 pounds; XXX—62 inches, 67 pounds.

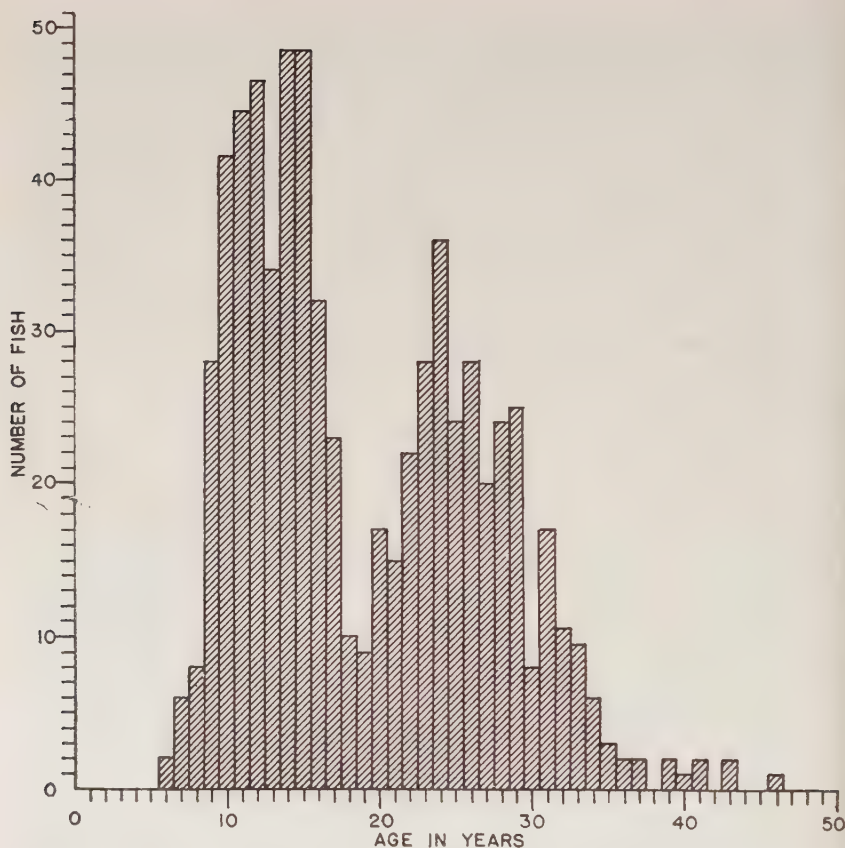


FIGURE 5.—Age-frequency distribution of 697 lake sturgeon speared in Lakes Poygan, Winneconne, and Butte des Morts.

marginal ray were considered too extreme to warrant an attempt to determine the relationship between fish length and fin-ray measurement. Unlike the spines employed in age determination of catfish, carp, or suckers, the marginal rays of lake sturgeon frequently have more than one center of radial growth, possibly due to the incorporation of the next posterior ray which otherwise remains uncalcified (Fig. 2). Some of the European workers, including Chugunov (1926) and Classen (1944) have reported success in back-calculating length values for sturgeon through the use of the Dahl-Lea formula.

As a group, the Acipenseridae are known to be slow growing and long lived. The lake sturgeon is no exception. Growth in length was most rapid during the first year, and decreased with little irregularity to the age of 14 years (Table 3). Irregularity in growth became more prominent

TABLE 3. — *Length and weight of lake sturgeon of different age groups taken from Lake Winnebago region during the months of October, November, January and February*
 [Ages are in completed, or nearly completed growing seasons. For convenience, arabic rather than roman numerals designate the age groups]

Age group	Total length (inches)			Weight (pounds)		
	Number of fish	Mean length	Range in length	Number of fish	Mean weight	Range in weight
1.....	2	7.7	7.1- 8.2	2	0.07	0.06- 0.07
2.....	13	14.4	12.5-17.5	13	0.47	0.28- 0.9
3.....	10	18.9	16.9-20.2	10	1.1	0.7- 1.4
4.....	9	22.8	20.8-25.7	9	2.1	1.5- 3.0
5.....	8	26.1	23.8-27.5	7	3.07	2.6- 3.5
6.....	6	31.5	27.5-35.0	6	6.1	3.3- 9.5
7.....	11	30.8	28.8-34.0	11	5.4	4.3- 9.5
8.....	14	33.1	29.5-36.0	13	7.4	4.5-12.0
9.....	33	34.4	30.5-39.0	30	7.8	5.0-15.0
10.....	47	35.7	32.0-44.0	47	9.0	5.0-18.0
11.....	74	37.0	33.0-42.0	71	10.1	6.3-19.5
12.....	51	38.8	33.5-45.0	50	11.6	7.0-21.0
13.....	40	40.6	34.0-51.0	38	14.6	8.0-31.0
14.....	59	41.2	37.0-51.0	58	14.9	10.0-35.0
15.....	62	44.5	37.0-56.0	62	18.9	7.0-38.0
16.....	41	44.5	34.0-57.0	41	18.3	8.0-34.0
17.....	30	45.7	41.0-51.0	29	21.8	13.8-36.0
18.....	12	48.8	43.0-56.0	12	25.7	14.0-40.0
19.....	13	50.3	44.0-57.0	13	27.9	17.5-43.0
20.....	16	49.8	44.0-56.0	16	29.0	15.0-42.0
21.....	16	50.7	46.0-54.0	15	29.8	22.0-40.0
22.....	23	51.0	45.2-58.8	23	29.1	16.0-45.0
23.....	29	50.0	38.0-57.0	29	31.3	9.0-42.0
24.....	42	52.7	41.5-63.0	41	34.8	17.0-70.0
25.....	33	53.7	44.0-62.5	33	37.3	24.0-65.0
26.....	43	56.9	45.0-69.0	43	41.0	21.0-91.0
27.....	24	56.1	51.8-65.0	24	40.8	27.0-61.0
28.....	39	57.4	46.5-64.0	39	43.7	28.0-70.0
29.....	31	56.4	48.0-63.0	31	45.1	30.0-72.0
30.....	22	60.6	55.8-71.0	22	54.9	28.0-99.0
31.....	27	61.1	51.0-72.0	27	55.4	31.0-82.5
32.....	24	61.7	56.0-76.0	23	59.0	42.5-94.0
33.....	13	62.6	54.3-69.5	13	57.9	47.0-68.0
34.....	14	62.4	56.0-66.5	13	60.9	45.0-80.0
35.....	5	65.2	58.0-70.0	5	68.6	57.0-90.0
36.....	11	65.8	59.0-70.0	11	68.0	56.0-96.0
37.....	8	66.1	60.0-69.0	8	65.4	50.0-81.0
38.....	2	58.5	57.0-60.0	2	68.5	68.0-69.0
39.....	3	65.0	61.0-67.0	3	78.0	62.0-87.0
41.....	3	67.7	61.0-72.0	3	76.3	65.0-96.0
43.....	1	70.0	.....	1	70.0	.....
49.....	1	72.0	.....	1	106	.....
82.....	1	79.0	.....	1	....	.....

between 14 and 19 years of age. After 19 years, annual increments in length were extremely variable. Classen (1944) observed marked changes in growth of *Acipenser sturio* at the ages of 8 and 9 years, and attributed the occurrence to alteration of the general metabolism, due to development of the gonads. Cuerrier (1949) reported that male lake sturgeon matured sexually at approximately 14 years of age and females in about 25 years. Due to the limited data on the age of lake sturgeon at sexual maturity from the Lake Winnebago area, it is difficult to determine the

effects of sexual maturity on changes in rate of growth in these populations.

Growth rate in length varies considerably among individual lake sturgeon of all ages (Table 3). In age-group I (young-of-the-year fish collected in October and November), lengths ranged from 7.1 to 8.2 inches and in age-group XXXII length ranged from 56.0 to 76.0 inches. Separate analyses of age-length data for Lake Winnebago and Lakes Poygan, Winneconne, and Butte des Morts gave evidence that Lake Winnebago fish were the larger at ages below 20 years. The average lengths for ages over 20 years are similar for all lakes. The difference in growth rates noted is possibly due to the limited number of lake sturgeon under 20 years of age collected from Lake Winnebago.

No difference is evident between the rates of growth in male and female lake sturgeon in Lakes Poygan, Winneconne, and Butte des Morts (Fig. 6). Classen (1944) noted a somewhat more rapid growth among females of *A. sturio*, but stated his observations to be insufficient to allow conclusions on sex differences in growth, since Russian authors insist that no essential differences exists in the growth rates of the sexes of *A. gueldenstaedti* and *A. stellatus*.

The age-length data for Lake Winnebago fish derived from the present

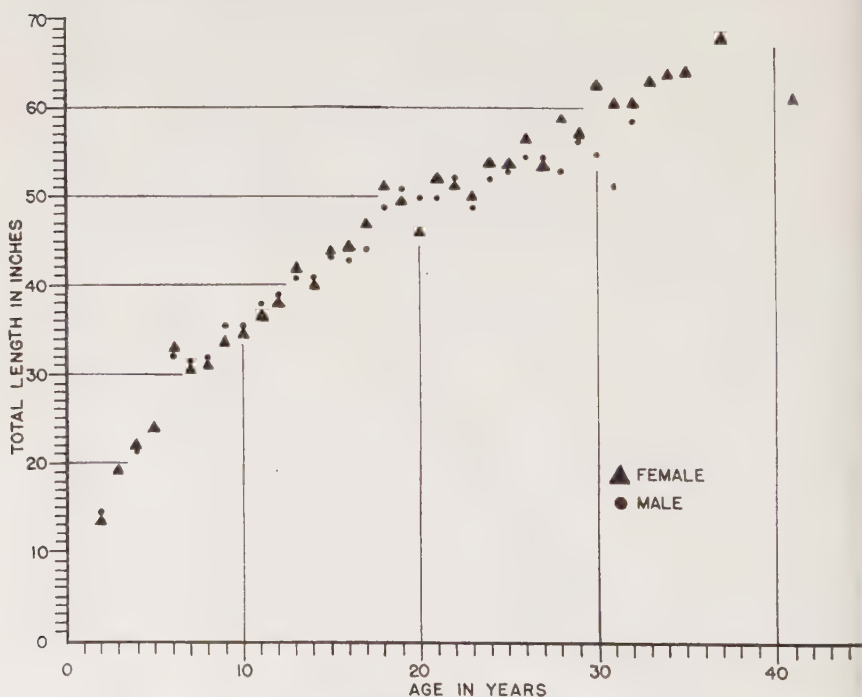


FIGURE 6.—Comparison of growth of male and female lake sturgeon in Lakes Poygan, Winneconne, and Butte des Morts.

study are somewhat similar to the findings of Schneberger and Woodbury (1946) who determined the ages of 35 lake sturgeon from the same lake by examining otoliths. Age determinations from otoliths ranged from 14 to 31 years and the relationship of length to age over this range was thought to approximate a straight line. It is believed that a larger range in sampling would have indicated the relationship of length to age to follow a curve (Fig. 7). However, it is of interest that the growth curve drawn from data of the present study is somewhat flattened and approaches a straight line between the ages of 10 and 30 years.

Lake sturgeon from Lake Winnebago and its associated waters attain larger sizes at given ages than in Lake St. Francis or in Lake Nipigon in Ontario (Table 4). Ages of the Lake St. Francis lake sturgeon were assessed by the marginal-ray-section method, whereas those of the Lake Nipigon material were determined from otoliths. The difference in the average weight values of given ages for the Lake Winnebago region and Lakes St. Francis and Nipigon is not due entirely to age, but partly to the length-weight relationship.

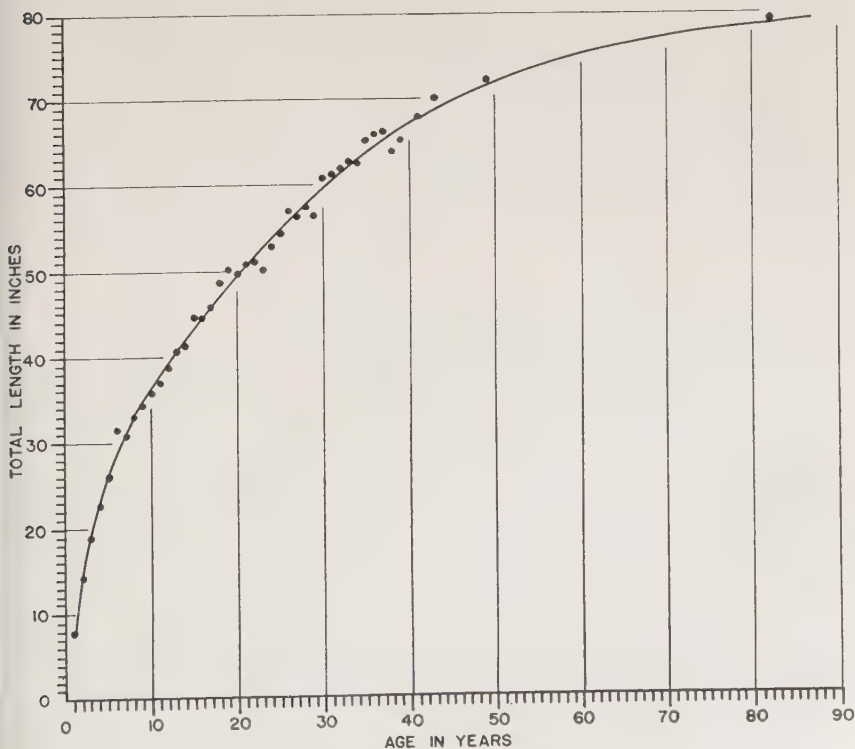


FIGURE 7.—Growth curve of lake sturgeon from Lake Winnebago region, data from all lakes combined.

TABLE 4. — Comparison of average total lengths and weights of lake sturgeon of various ages from the Lake Winnebago region (present study), Lake Winnebago (1946), Lake St. Francis and Lake Nipigon

[Lengths in inches, weights in pounds]

Age years	Present study		Lake Winnebago 1946 ¹		Lake St. Francis 1951 ²		Lake Nipigon 1923 ³	
	Length	Weight	Length	Weight	Length	Weight	Length	Weight
5.....	26.1	3.1	....	....	24.4	2.7	19.8	1.2
10.....	35.7	9.0	....	....	31.9	6.3	26.2	3.1
15.....	44.5	18.9	47.4	....	38.2	12.5	30.8	4.9
20.....	49.8	29.0	51.9	....	43.6	18.9	35.7	9.8
25.....	53.7	37.3	56.3	....	....	....	39.5	12.0
30.....	60.6	54.9	60.8	....	....	....	....	....
35.....	65.2	68.6	....	....	....	....	53.4	42.0

¹ From Schneberger and Woodbury (1946). Calculated length values.

² From Cuerrier and Roussow (1951).

³ From Harkness (1923).

⁴ Average length and weight values for 19 years of age.

⁵ Average length and weight values for 37 years of age.

The shape of the growth curve drawn from data from the Lake Winnebago area would indicate that the maximum size attained by this species of sturgeon is slightly in excess of 80 inches (Fig. 7). The oldest fish taken from the Lake Winnebago area was 79 inches long and was approximately 82 years old. This interpretation of the growth curve is corroborated by the collection of an 81-inch lake sturgeon from Lake of the Woods, Ontario in 1953 by a fisherman. Examination of a fin bone removed from the fish indicated an age of approximately 152 years. (Anonymous, 1954).

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship of lake sturgeon, determined from all data combined, was computed to be:

$$\log W = -4.17096 + 3.30367 \log L,$$

where W is weight in pounds and L is total length in inches (Fig. 8). These data were combined because of the relatively few fish from Lake Winnebago and the pronounced difference in length-frequency distributions for lake sturgeon from Lake Winnebago and Lakes Poygan, Winneconne, and Butte des Morts (Fig. 1).

As would be expected, the greatest discrepancies between actual and computed weights came at length intervals represented by few fish, especially in lengths over 65 inches. Part of the disagreement between the actual and computed weight values for lengths over 47 inches may be attributed to the combination of all available data. The mathematical relationship is based on data of 799 fish from Lakes Poygan, Winneconne, and Butte des Morts and 185 collections from Lake Winnebago. Separate analysis of the length-weight data for Lake Winnebago fish resulted in the solution:

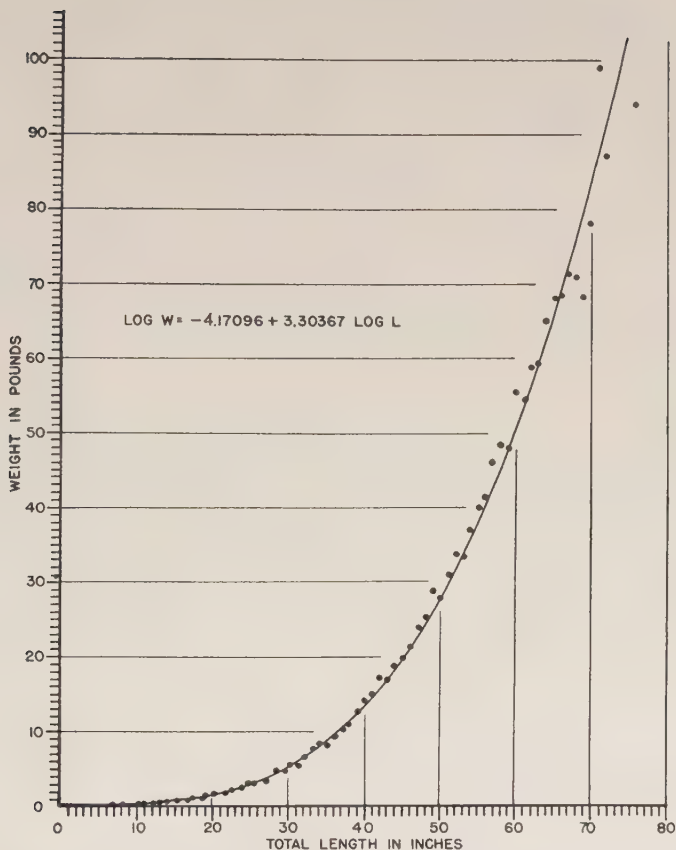


FIGURE 8.—Length-weight relationship of the lake sturgeon from Lake Winnebago region, all data combined. The smooth curve is the solution of the equation; the dots show the actual weights at various lengths.

$$\log W = -4.01939 + 3.24070 \log L,$$

while that for Lakes Poygan, Winneconne, and Butte des Morts yielded the following solution:

$$\log W = -4.12298 + 3.26625 \log L.$$

Although the weight of the fish increases as to approximately the same power of the length in both populations, computed weight values for Lake Winnebago fish averaged somewhat heavier than those from Lakes Poygan, Winneconne, and Butte des Morts: at 30 inches, 5.9 to 5.0 pounds; at 40 inches, 14.9 to 12.6 pounds; at 50 inches, 30.7 to 26.7 pounds; and at 60 inches, 55.3 to 48.4 pounds, respectively.

The length-weight relationships of 288 males and 263 females from

Lakes Poygan, Winneconne, and Butte des Morts were practically identical. For the males the length-weight equation was:

$$\log W = -4.10243 + 3.25418 \log L$$

while that for the females was:

$$\log W = -4.12597 + 3.26261 \log L$$

Computed weight values derived from these solutions differ by only 0.94 pound at the 60-inch length.

The average coefficient of condition (*C*) for 981 lake sturgeon from all localities was 21.7. Lake Winnebago fish were somewhat plumper than lake sturgeon from the smaller lakes. The average coefficient of condition for 184 Lake Winnebago lake sturgeon was 25.4, and that for 797 lake sturgeon from the other lakes was only 20.9.

SEX RATIO OF THE CATCH

In Lakes Poygan, Winneconne, and Butte des Morts the sexes were nearly equal in abundance, with females accounting for 53.6 percent of the 491 fish examined. In Lake Winnebago, however, females were much more numerous, composing 72.4 percent of the 163 lake sturgeon.

Analysis of the sex ratio with change in size in the small lakes revealed that the sexes were approximately equal in abundance up to the length of 59 inches (Table 5). Among fish over 59 inches long, the females accounted for 96 percent of the total.

TABLE 5. — *Sex ratio of lake sturgeon from Lakes Winnebago, Poygan, Winneconne and Butte des Morts compared with size of fish and place of collection*

Total length (inches)	Lakes Poygan, Winneconne and Butte des Morts		Lake Winnebago	
	Number of fish	Percentage female	Number of fish	Percentage female
30-39.....	140	52.9	10	30.0
40-49.....	159	42.8	29	37.9
50-59.....	142	51.4	52	67.3
60-79.....	50	96.0	72	95.8

In Lake Winnebago, males dominated the catch up to 49 inches. In the 50- to 59-inch group, 67 percent of the catch were females and in the 60- to 79-inch group, 96 percent were females.

An examination of the sex ratio on a basis of age groups reveals a picture similar to that when size was considered (Table 6). Males and females were equally abundant in the catch of the smaller lakes up to age-group XXIX, but females constituted 94 percent of the catch over 30 years of age. In Lake Winnebago females made up the majority of the catch over 20 years old.

Females live longer and thus grow to larger sizes than do the males in

TABLE 6. — Sex ratio of lake sturgeon from Lakes Winnebago, Poygan, Winneconne and Butte des Morts compared with age of fish and place of collection

Age (years)	Lakes Poygan, Winneconne and Butte des Morts		Lake Winnebago	
	Number of fish	Percentage female	Number of fish	Percentage female
1-9.....	28	57.1	6	16.7
10-19.....	251	47.0	43	41.9
20-29.....	166	50.6	41	68.3
30-82.....	46	93.5	66	96.9

the Winnebago area. This sex difference in age attained may be due to either a longer natural life span of the females or to a lower rate of exploitation. A higher rate of exploitation for males is a possibility if illegal harvesting by snag lines during spawning runs in the Wolf River contributes significantly to the mortality of the species. It is commonly observed that several males will be taken together with a single female during these operations. Classen (1944) indicated that the sexual life of male Atlantic sturgeon is very short compared to that of the female, due to elimination from the fishery by natural causes or by fishing mortality.

Cuerrier and Roussow (1951) found a ratio of 68 females to 66 males in a commercial fishery in Lake St. Francis where the average size of the fish was approximately 30 inches. In another widespread of the St. Lawrence River, Lake St. Peter, the largest ripe male collected was 53.5 inches, fork length, which is equivalent to 58.4 inches total length (Cuerrier, personal communication). The oldest male taken in Lake St. Peter was 39 years old; few were older than 30 years.

According to data presented by Classen (1944) on the sex ratio of *A. sturio* in Spain, only one male out of 175 was older than 17 years; for females 77 percent of 156 fish were more than 17 years of age. Bajkov (1930) observed most of the heavier fish to be females. In the Lake Winnebago data previously reported by Schneberger and Woodbury (1946) the largest male was 60 inches long, but eight females from 60 to 67 inches long were taken.

FOOD HABITS

The feeding habits of lake sturgeon apparently differ according to the availability of food items. The most important food items in Lake Winnipeg were the fish-fly (*Hexagenia limbata*), mollusks, and crayfish (Bajkov, 1930). In Lake Nipigon, lake sturgeon were eating primarily ephemeropterid nymphs, chironomid larvae, and mollusks (Harkness, 1924). In Lake Pepin, ephemeropterid larvae seemed to be predominant in the diet of lake sturgeon (Wagner, 1908). All of these studies were made on fish collected during the spring and summer months.

During February 1954, the stomach contents of 554 lake sturgeon from 30 to 76 inches long were examined. Material occurring only in the

anterior portion of the stomach could be identified. Food items here were characteristically clean and entire with detritus very seldom present. Most of the fish from Lake Winnebago had been actively feeding; only 12 percent of the stomachs were empty (Table 7). This situation was in marked contrast to that in the smaller lakes where 54 percent of the stomachs were empty.

Tendipedid larvae were the most important food item taken by the lake sturgeon, especially in Lake Winnebago (Table 7). In the smaller lakes, mayflies and aquatic sow bugs were also taken frequently. Leeches occurred in about 10 percent of the stomachs from Lake Winnebago. The fish remains occasionally noted in the stomachs usually showed evidence of being discarded bait minnows.

TABLE 7.—Occurrence of various food items in stomachs of lake sturgeon from Lakes Winnebago, Poygan, Winneconne, and Bulte des Morts collected during February 1954

Food item ¹	Percentage frequency of occurrence of food items in all stomachs examined		Food item ¹	Percentage frequency of occurrence of food items in all stomachs examined	
	Lake Winnebago	Small lakes		Lake Winnebago	Small lakes
Nematomorpha.....	....	0.5	Ceratopogonidae...	1.6	3.3
Hirudinea.....	10.2	0.2	Gastropoda.....	....	0.2
<i>Asellus</i>	0.8	14.8	Pelecypoda.....	2.4	0.2
<i>Hyalella</i>.....	....	0.5	Fish remains.....	1.6	4.0
Ephemeroptera.....	1.6	19.2			
<i>Stalis</i>	4.7	5.6	Number of stomachs..	127	427
Trichoptera.....	....	0.2	Percentage empty..	11.8	53.9
Tendipedidae.....	86.6	27.6			

¹ Classification after Pennak (1953)

ACKNOWLEDGMENTS

Grateful appreciation is due the many sturgeon spearers and interested sportsmen whose generous cooperation made possible the collection of much of the material upon which this report is based. Assistance from the many department personnel who were engaged in collecting field data is also acknowledged.

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THE LENGTH AND GROWTH OF 0-YEAR CLASS CREEK CHUBS IN RELATION TO DOMESTIC POLLUTION

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ABSTRACT

The lengths of creek chubs, *Semotilus a. atromaculatus*, of the same year class differ significantly in the various pollutional zones of Lytle Creek, Clinton County, Ohio. In the clean-water zone above a sewage treatment plant outfall, where the stream is very small, the 0-year creek chub taken in August 1952 averaged 42.3 millimeters in total length. The creek chubs of the same year class, found in the upper portion of the recovery zone, averaged 53.3 millimeters, while in the enriched lower portion of the recovery zone they were larger, averaging 63.8 millimeters. In the lower clean-water zone, the fish were smaller and had a mean length of 52.0 millimeters.

In the upper recovery zone, the creek chubs apparently did not survive the winter season. Despite a considerable minnow fishery, significant numbers of 1-year-old or older fish were present in the upper clean-water zone, lower recovery zone, and lower clean-water zone.

Growth was rapid in the upper recovery zone during the early summer, but slowed down markedly by the end of the summer, while growth at the other stations remained rapid into the early fall. Growth could not be correlated with the volume of bottom organisms found at the various stations. The consistent difference in the size of creek chub at the various stations indicates that these fish do not migrate in search of optimum conditions.

INTRODUCTION

Spectacular fish kills are often investigated by aquatic biologists; but attention is seldom paid to populations surviving in waters where sub-optimal conditions resulting from pollution allow some tolerant fish species to persist. There are a few interesting although sketchy reports on changes in fish populations that have survived major fish kills or have been subjected to chronic pollution. Dendy (1952) made brief but valuable observations on the reduction of the fish population of an Alabama stream as a result of a fish kill. Others who have reported the composition of fish populations in polluted and unpolluted sections of some waters are Carpenter (1930), Trautman (1933), Thompson and Hunt (1930), McKenzie (1930), Gerking (1947), and Jackson and Henderson (1942).

Some observers have ascribed certain pathological manifestations to pollutants. Brinley and Katzin (1944) observed that fish collected downstream from a sewer outfall were "sickly, abnormal, or parasitized."

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Thompson (1928) correlated the incidence of knothead disease of Illinois river carp with increases in domestic waste discharges. O'Donnell (1935) suggested that some osteological abnormalities of a carp might be connected with pollution. Hubbs (1933) mentioned an increased incidence of bacterial diseases and encysted trematodes in fish residing in polluted waters. He also stated that, "Fish may become much dwarfed in polluted waters; thus in the River Raisin, I have found two- and three-year-old carp below Monroe to be about the size of yearling carp above town and to have only a fraction of the weight shown by the carp of the same age in unpolluted water." Our findings on the growth of Lytle Creek chubs indicate a different situation.

Domestic wastes are not necessarily deleterious to fish. For example, raw sewage and sewage plant effluents are standard fertilizers in fish-cultural establishments of Europe and Asia (Ganapati and Chacko, 1950). In Lake Erie, sport fishing was stimulated near the Lakewood, Ohio, sewage disposal plant outlet (Metcalf, 1942). Metcalf showed that the biota in the effluent supported populations of micro-crustacea which in turn attracted minnows and white bass. Hubbs (1933) believed that the sustained fish production of Lake Erie was due to fertilization of the lake by the wastes of the adjacent human population. Hubbs also noted the increased yield of the Illinois River fisheries observed after the sanitary sewage of Chicago was diverted into that river. Cross (1950) reported an increase in the catch in Stillwater Creek, Oklahoma, after raw sewage was diverted into the stream. It was noted, however, that a newly erected impoundment had stabilized stream flows.

To determine more accurately the effects of sewage on fish populations, as well as to investigate other phases of the biology of sewage polluted streams, the Biology Section of the Robert A. Taft Sanitary Engineering Center has been studying the effects of the partially treated domestic sewage of Wilmington, Ohio, on the fauna of the receiving stream, Lytle Creek. Gaufin and Tarzwell (1952) studied the bottom invertebrates of the various pollutional zones of the creek and correlated the numbers and species of macro-invertebrates with degree of pollution, seasons, and physical and chemical conditions at the various stations.

Katz and Gaufin (1953) observed that as the sewage was borne downstream and purified by biological processes, the number of fish species as well as the total population increased with the degree of purification.

This paper deals with the effect of Wilmington sewage upon the growth of creek chubs, *Semotilus a. atromaculatus*, found in the different pollutional zones of Lytle Creek. It will be shown that there is a marked difference in the size of these fish in the various zones of the creek.

PROCEDURES

Fish were collected with seines of $\frac{1}{4}$ -inch square mesh. Samples were taken at five stations on Lytle Creek representing polluted and clean-water zones. The number assigned to each of these stations corresponds to the

distance in miles above the confluence of Lytle Creek with Todd's Fork of the Little Miami River. The pollutional zones represented are as follows: upper clean-water zone, Stations 9.5 and 8.7, recovery zone, Station 4.2 and 2.8, clean-water zone, Station 1.0. The Wilmington sewage treatment plant outlet is 7.2 miles above Todd's Fork, between Stations 8.7 and 4.2. During the summer, septic conditions create a fishless area in Lytle Creek extending almost 3 miles downstream from the sewage plant outlet.

Although the creek chub is known to be a tolerant species, it was selected for these growth studies because it is the predominant fish in Lytle Creek, and can be taken at all stations where fish exist. Most of the fish used in this study were taken during the monthly collections of February through September 1952.

All stations were sampled on the same day. The fish collected were immediately preserved in 8-percent formalin and taken to the laboratory where they were sorted, identified, and measured. The total length (the distance from the tip of the snout to the tip of the caudal fin with that appendage in a natural position) was measured to the nearest millimeter. Age was determined by scale readings. Because of the small numbers of older fish, individuals of the 0-year group only were considered in evaluating relative growth rates.

LENGTH OF THE 0-YEAR CLASSES IN THE VARIOUS ZONES

There were marked and significant differences in the mean total lengths of the 0-year class of creek chubs taken at different stations (Table 1). On the same data the mean length of the specimens taken at Station 2.8 was consistently larger than the fish collected at any other station. The chubs taken at Stations 8.7 and 9.5, which are well above the sewage treatment plant outlet, were very small. The largest creek chub taken at Station 8.7 on August 25, 1952, (Fig. 1) was smaller than the smallest taken on the same day at the fertile Station 2.8. Chubs taken at Station 4.2 (upper recovery zone), where the fishes (populations) were small in number and few in species, had about the same mean lengths on corresponding dates as the fish taken at Station 1.0 (lower clean-water zone), an area rich in number and species of fish. The individuals at Stations 4.2 and 1.0 were significantly smaller than those taken at Station 2.8 but were larger than those taken at the upper clean-water Stations, 9.5 and 8.7.

The growth of creek chub in the various zones of Lytle Creek as represented in the curves of Fig. 2 is markedly different. Fish at the upper recovery zone, Station 4.2, grew very rapidly between June 17–July 23, but the rate declined during the following monthly interval, and no appreciable growth was observed between August 25 and September 24. At Station 1.0, the chubs did not grow as rapidly during June 17–July 23, but maintained the same growth rate during the subsequent two monthly intervals.² The growth curves of the other stations were similar to those of Station 1.0.

² In attaching significance to differences in mean lengths, it must be assumed that the chubs hatch at about the same time in May at each station. No evidence to the contrary is available.

TABLE 1.—The mean total length (millimeters) of 0-year classes of creek chubs at the various stations and the “*t*” values of those at adjacent stations
 [Number of specimens in parentheses]

Date of Collection	Stations							
	9.5	“ <i>t</i> ” ¹	8.7	“ <i>t</i> ”	4.2	“ <i>t</i> ”	2.8	“ <i>t</i> ”
1950 year class								
October 23, 1950.....	.....	.....	.....	.....	.....	.....	70.3 (36)	211.54
1951 year class								
February 29, 1952.....	.....	.....	.....	.....	.....	.....	71.3 (73)	214.25
March 21, 1952.....	.....	.....	.....	.....	.....	.....	72.1 (84)	20.27
April 27, 1952.....	.....	.....	.....	.....	.....	.....	66.0 (13)	4.77
May 26, 1952.....	.....	.....	.....	.....	.....	.....	76.4 (5)	.....
June 17, 1952.....	.....	.....	.....	.....	.....	.....	76.4 (58)	.....
1952 year class								
June 17, 1952.....	.....	.....	.....	.....	28.4 (27)	.....	.....	31.1 (14)
July 23, 1952.....	.....	.....	.....	.....	46.4 (28)	22.99	50.7 (33)	26.55
August 23, 1952.....	.....	.....	42.3 (28)	26.55	53.3 (40)	27.72	63.8 (264)	27.88
September 24, 1952.....	48.2 (54)	1.60	49.6 (43)	.....	54.8 (6)	.....	73.2 (111)	14.68
								58.7 (95)

¹ The “*t*” for 50 degrees of freedom at the 99% level of significance is 2.67. “*t*” was calculated only when comparing collections totaling more than 52 fish.

² In these cases, the variances in the lengths in each sample were significantly different, therefore, the ordinary *t*-test does not apply. Instead, Welch’s modified *t*-test was used (see Kendall, Advanced theory of Statistics. Vol. II, p. 114).

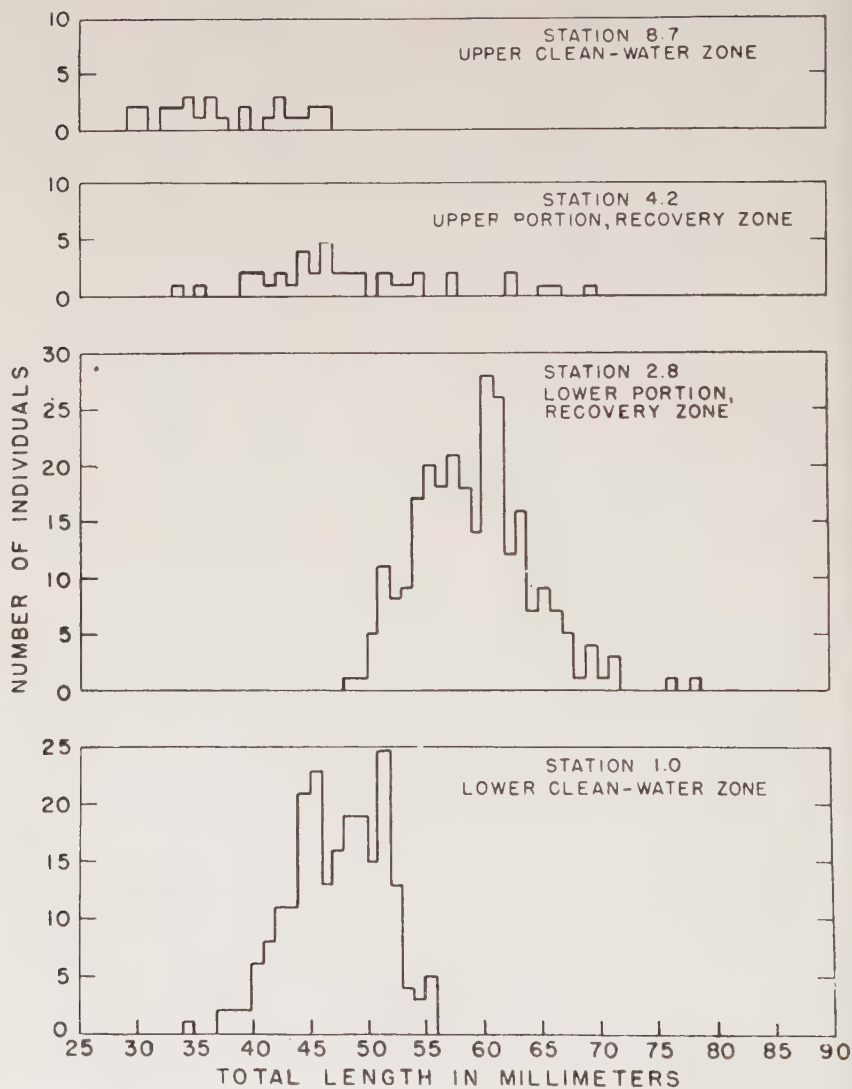


FIGURE 1.—Length-frequency polygon of 0-year class of creek chubs taken in the various zones of Lytle Creek, on August 25, 1952.

The collections taken in the early spring months of 1952 indicate that these differences in size were consistent from year to year. Chubs of the 1951 0-year class taken at Station 2.8 were found in each sample to be larger on the average than those of Station 1.0 (Table 1). The same sit-

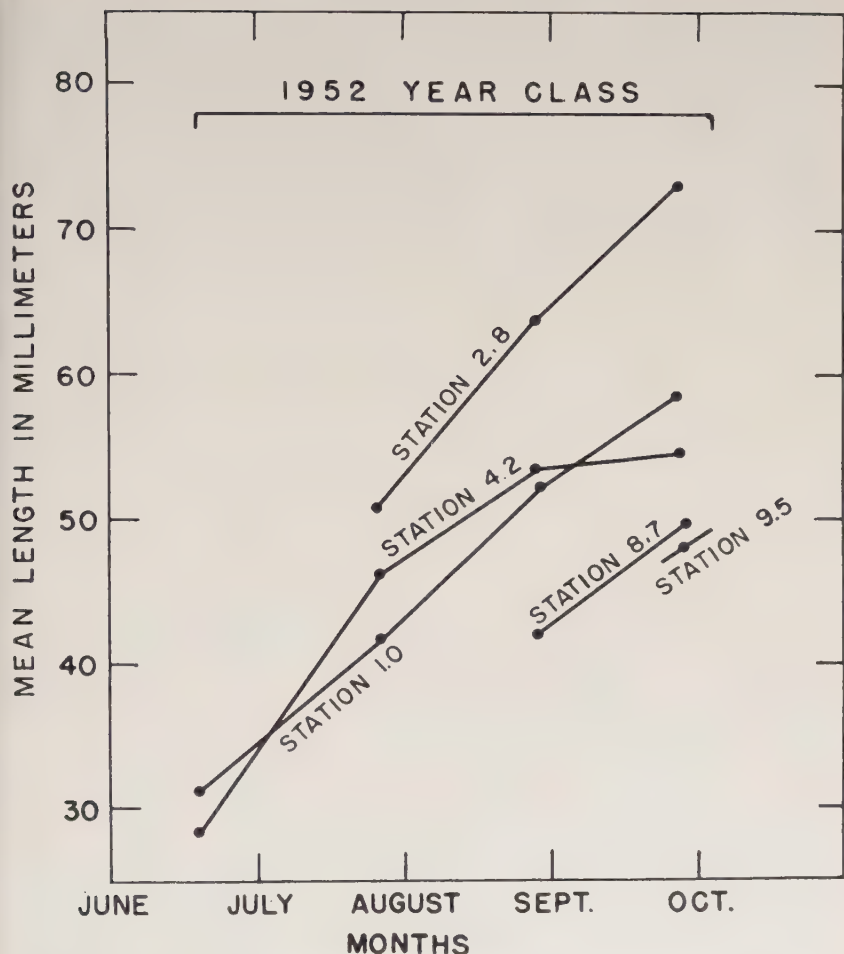


FIGURE 2.—The growth curves of the 1952 year class of creek chubs in the various zones of Lytle Creek.

uation was found in the 0-year class of 1950, sampled in October of that year.

The marked differences in the mean lengths and growth rates of the creek chubs suggest that in this stream, the species is not a single population intermingling at random, but consists of several independent populations each of which remains in a relatively small area. The data indicates the fish are non-migratory, at least during their first year of life. If the individuals had migrated freely, the differences in the average size of the fish at the different stations would have been obliterated by the inter-

mingling of fish from the various populations. Similar differences in growth of fish in various areas of a relatively small stream have been noted in brown trout by Allen (1951). A tendency for fish to remain in a restricted "home" territory has been reported by Gerking (1950, 1953) and Stefanich (1952).

Scale readings made for the fish of the large August 25, 1952, collection revealed differences in the age composition in the various zones (Table 2). All fish at Station 4.2 (upper recovery zone) were of the 0-year class although this station is distant from any road and is not visited by minnow seiners. On the other hand, a significant proportion of fish at Stations

TABLE 2.—*The percentages of 0-year class and older creek chubs taken on August 25, 1952, at various stations on Lytle Creek*

Station	Number of fish	Percentage of fish belonging to	
		0-year class	1-year class or older
8.7.....	30	93.3	6.7
4.2.....	40	100.0	0.0
2.8.....	310	84.8	15.2
1.0.....	267	83.5	16.5

8.7, 1.0, and 2.8 (upper and lower clean-water zones, and the lower recovery zone, respectively) were one year or older despite considerable predation by minnow fishermen. Natural mortality at Station 4.2 is obviously high, and it is assumed that the population at this station is replenished annually by the offspring of chubs which migrate from downstream areas during the spring spawning migration.

FACTORS POSSIBLY INFLUENCING GROWTH OF CREEK CHUBS

Previous observations on Lytle Creek (Katz and Gaufin, 1953) showed that pollution by domestic wastes makes certain sections of the stream unsuitable for fish and reduces the number of species and individuals in other affected portions of the stream. The data presented above shows that the pollution of Lytle Creek has an effect on the growth of at least one species of fish, the creek chub.

The growth of Lytle Creek chubs has been compared with those collected in other areas of Ohio and North America (Table 3). A great variation in the average length of this species from different locales is indicated.

During the first few months of growth, the rapidly growing chubs at Station 2.8 were larger than the well-fed Ohio hatchery fish studied by Clark (1943), but they grew more slowly than the Ohio hatchery specimens during the fourth month. Michigan hatchery fish studied by Dobie *et al.* (1948) exhibited a continuously high rate of growth during the third and later months. Chubs at Station 2.8 were considerably larger than older fish taken by Hart (1952) in Tennessee and Ontario. The Lytle Creek

fish did not show an increase in size after the first summer comparable to that of hatchery fish of Michigan.

Among the factors that can be evaluated in accounting for differences in chub growth among the various zones of Lytle Creek are food supply, stream flow, dissolved oxygen content of the water, and the effects of the sewage effluent.

Dobie, Meehan, and Washburn (1948) state that the omnivorous creek chub feeds on vegetable matter, aquatic and terrestrial insects, crawfish,

TABLE 3.—*The growth of creek chubs from various locations*

[All lengths are given in millimeters]

Locality	Months of growth				Years of growth		
	1	2	3	4	1 plus	2	2 plus
Knoxville, Tenn. ¹.....	....	....	....	....	258.1	....	277.5
Toronto, Canada ³.....	....	....	....	....	229.0	....	268.7
Michigan Hatchery ⁴	25.4	38.0	63.4	81.3	127.0	178.0	....
Ohio Hatchery ⁵	30.4	....	45.7	68.6	....	....	....
Lytle Creek, Ohio							
Station 8.7.....	....	....	42.3	49.6	....	....	....
Station 4.2.....	28.4	46.4	53.3	54.4	....	....	....
Station 2.8.....	....	50.7	63.8	73.2	76.4	....	....
Station 1.0.....	31.1	41.6	52.0	58.7	62.1	....	....

¹ Collected July 15, 1947, (Hart, 1952)

² Standard Length. Other measurements are total lengths

³ Collected August 8, 1947, (Hart, 1952)

⁴ Dobie *et al.* (1948)

⁵ Clark (1943)

small fish, snails, and any other available organisms. Previous investigations (Gauvin and Tarzwell, 1952) indicated that bottom macro-invertebrates were abundant throughout Lytle Creek. The volume of potential food organisms was greatest in the upper recovery zone, Station 4.2. At this station, they were about three times as abundant as in the lower recovery and clean-water zones, Stations 2.8 and 1.0.

Despite this large potential food supply, the fish population at Station 4.2 remained small in numbers and species and growth fell off markedly during August and September, in contrast to the continuing rapid growth of the large populations at Stations 2.8 and 1.0 during the same period. A possible explanation may lie in the marked difference in composition of the invertebrate bottom fauna from one station to another. We have no knowledge of the food preferences of creek chub in Lytle Creek or of the relative availability of the different organisms to the fish. A study of the stomach contents of fish taken at the various stations would be desirable.

Stream flow is another factor believed to be involved in the growth of the creek chubs in Lytle Creek. The very dry summer of 1952 resulted in a lack of detectable flow at the upper clean-water stations of Lytle Creek, 9.5 and 8.7. Fish of all species were confined to shallow, isolated pools. Intense competition for food was probably an immediate factor limiting growth at these stations. It is known (Thompson and Hunt, 1930) more-

over that fish from small streams are smaller than fish of the same species from larger streams.

Below the outlet of the sewage treatment plant, Lytle Creek had an adequate flow of about 1 to 2 cubic feet per second and the stream had the normal variety of riffle and pool habitats.

The dissolved oxygen data reported by Gauvin and Tarzwell (1952) in their Table 1 suggest a possible reason for the inferior growth of chubs at Station 4.2 in the late summer and early fall. In a 24-hour series of oxygen determinations taken hourly on August 22 and 23, 1951, the maximum dissolved oxygen at Station 4.2 was 5.5 p.p.m. and the minimum 2.0 p.p.m. At Station 2.8, the maximum dissolved oxygen was 14.7 p.p.m. and the minimum, 3.2 p.p.m.; and at Station 1.0, the maximum was 9.6 p.p.m., the minimum, 5.3 p.p.m.

The low dissolved oxygen content of the water at Station 4.2 may have limited the foraging activity of the fish resident there. In fact, all species of fish at this station were restricted to rather definite areas of the pools and were found only immediately below riffles where the oxygen content was somewhat higher because of the mechanical aeration of water. Growth at Station 4.2 was most rapid in June and July, when days were longest. During these months, the photosynthetic activity of phytoplankton supplemented the oxygen content of the water. The long days allowed the fish to forage under adequate oxygen conditions. The hours during which dissolved oxygen was adequate for foraging activities became less as the season progressed. By the end of August, growth of the creek chubs at this station had almost stopped. The fewer hours during which the stream water had an adequate dissolved oxygen content allowed the fish opportunity to collect only enough food to maintain themselves.

The rapid growth, large size, and abundance of creek chubs at Station 2.8 may reflect a beneficial fertilizing effect of the Wilmington sewage effluent on the aquatic life. At Station 1.0 (lower clean-water zone) the fertilizing effects of the sewage was no longer obvious and the fish (Table 1) were significantly smaller.

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SOME ECOLOGICAL RELATIONSHIPS BETWEEN YELLOW PERCH AND CUTTHROAT TROUT IN THOMPSON LAKES, MONTANA

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ABSTRACT

The relationship between yellow perch and cutthroat trout in Thompson Lakes, Montana, was investigated in the summers of 1952 and 1953. These lakes originally contained cutthroat trout and were later planted with yellow perch. The spawning time of the yellow perch was in early May, and for the cutthroat trout in late May. The population of yellow perch was large and growth was very slow. Although the number of cutthroat trout was small, the growth rate for this species was about average. The food of yellow perch was largely immature aquatic insects and plankton while that of cutthroat trout was mostly mature aquatic insects and small perch. Yellow perch were commonly distributed along the lake margins and concentrations of perch fry and adults were found in these areas in the spring. During this period the salmonid fishes were predominately in the deep water. Spot poisoning of the yellow perch concentrations practically destroyed all of the fish in the treated area. Management suggestions are given.

INTRODUCTION

While many studies of the yellow perch (*Perca flavescens* Mitchill) have been made, only a few concern the relationships between yellow perch and trout. Swynnerton and Worthington (1940) examined the food of perch and trout in Haweswater (Westmoreland) and found little competition. Worthington (1949) studied the fishes of Lake Windermere, a perch infested trout lake, and concluded that a reduction of perch would be beneficial to the trout fishery. No studies of this kind are known in the United States. In western Montana there are many lakes which have been contaminated by the introduction of yellow perch. In most cases the trout fishery has apparently suffered from this introduction. An investigation on the ecological relationships of yellow perch, trout, and other fishes in the Thompson Lakes, Lincoln County, Montana (Fig. 1), was initiated in the summer of 1952. Work was renewed in the spring of 1953, and continued through the following summer.

The three lakes selected are perch-infested trout lakes which are readily accessible to fishermen. They are approximately 50 miles west of Kalispell on U. S. Highway No. 2. These lakes are connected by short channels and

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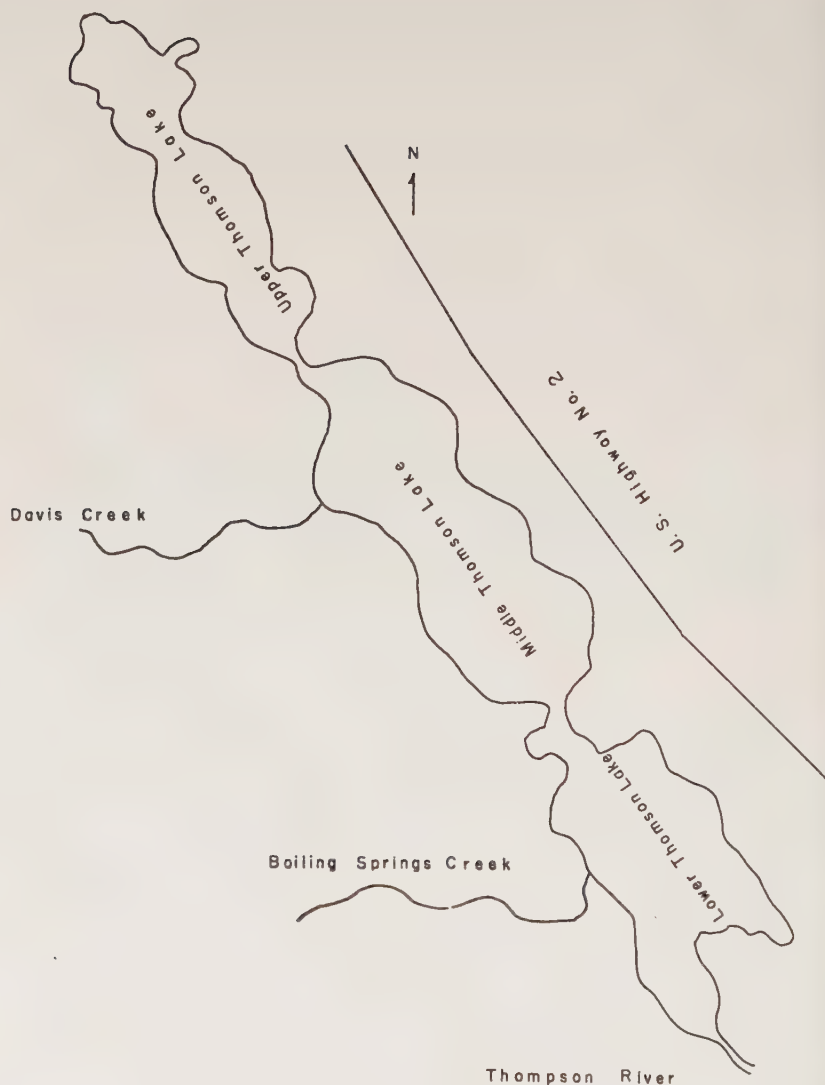


FIGURE 1.—Thompson Lakes, Lincoln County, Montana.

comprise the headwaters of the Thompson River. Their approximate areas and maximum depths are: Upper Thompson, 375 acres, 50 feet; Middle Thompson, 730 acres, 160 feet; and Lower Thompson, 240 acres, 150 feet.

About 25 percent of Lower and Middle Thompson Lakes and nearly 90

percent of Upper Thompson Lake is less than 10 feet deep. The maximum surface temperature near the middle of the Lower Lake was 75° F. (July 11, 1953). Lower and Middle Thompson Lakes were found thermally stratified in each year studied. Additional physical and chemical data are given in Table 1.

The game fish (Montana designation) found in Thompson Lakes were: kokanee (*Oncorhynchus nerka kennerlyi*), cutthroat trout (*Salmo clarki*), rainbow trout (*Salmo gairdneri*), eastern brook trout (*Salvelinus fontinalis*).

TABLE 1.—Physical and chemical data for Thompson Lakes in 1952 and 1953

Item	Date	Depth (feet)	Thompson Lakes		
			Lower	Middle	Upper
Temperature (°F.).....	June 16, 1952	0	59.0	59.0	60.5
	do.	15	59.0	59.0	60.5
	do.	36	42.0	41.5	43.0
	Sept. 4, 1952	0	65.0	65.0	66.0
	do.	25	54.5	58.0	62.0
	do.	35	45.5	45.0	50.0
	June 26, 1953	2	60.0	60.0	....
	do.	18	54.0	59.5	....
	do.	30	43.5	44.0	....
	Sept. 1, 1953	2	64.5	66.0	....
	do.	22	63.5	65.0	....
	do.	35	45.0	46.5	....
Dissolved oxygen (p.p.m.).....	July 21, 1952	15	8.5	8.0	8.4
	do.	35	3.5	4.0	2.5
	Sept. 4, 1952	15	8.0	8.0	8.0
	do.	35	1.8	4.3	6.1
	July 21, 1953	35	3.0	4.2	....
	Sept. 1, 1953	35	2.0	3.5	....
Secchi disc (feet).....	June 16, 1952	..	28	23	17
	Sept. 4, 1952	..	32	30	23
	July 21, 1953	..	18	18	....
	Sept. 1, 1953	..	24	25	....
Methyl orange alkalinity (p.p.m.).....	Sept. 4, 1952	2	236	220	228
	July 21, 1953	2	230	232	....
pH.....	Sept. 4, 1952	0	8.4	8.4	8.3

lis), dolly varden (*Salvelinus malma*), mountain whitefish (*Prosopium williamsoni*), and largemouth bass (*Micropterus salmoides*). The most abundant of these was the mountain whitefish with kokanee second and cutthroat trout third. Yellow perch (*Perca flavescens*) was the most abundant non-game fish. Pumpkinseed sunfish (*Lepomis gibbosus*) and squawfish (*Ptychocheilus oregonensis*) were common while longnose sucker (*Catostomus catostomus*) and Columbia large scale sucker (*Catostomus macrocheilus*) were abundant. The reidside shiner (*Richardsonius balteatus*) was scarce.

SPAWNING

An attempt was made to determine the relationships of yellow perch and cutthroat trout at each stage of their life cycles. If yellow perch proved to be vulnerable to control at some life history stage they might be reduced in favor of the trout.

Yellow perch.—The first ripe males and nearly ripe females of yellow perch were caught near a known spawning area in Lower Thompson Lake in late April, 1953. On May 5, several ribbons of eggs were found on the branches of a submerged pine tree in this area (surface water temperature 57° F.). On May 6, eggs were found to be common in the littoral zones of all three lakes. Clusters were observed from the surface to a depth of about five feet; usually near three feet. Yellow perch deposited their eggs on the following substrata in the Thompson Lakes: conifers (*Pinus ponderosa* and *Pseudotsuga taxifolia*), birch (*Betula fontinalis*), bulrush (*Scirpus validus*), and stonewort (*Chara*). In the order named the largest number of egg clusters was found on the submerged conifers and the smallest on *Chara*. A few eggs were seen directly on the bottom in areas without vegetation. The trees noted in the above observations were, in most cases, those that had fallen over from the shore into the lake.

An experiment was conducted to determine whether female yellow perch showed preference in the type of substrata used for spawning. Two likely areas were selected in Lower Thompson Lake and three structures; an 8-foot fir tree, a 10-foot birch tree without leaves, and a 2 by 8 foot chicken-wire grid were placed in each. These structures were located in a favorable spot near the bottom. Egg clusters were removed daily. The experiment continued from May 2 to May 29, and in this interval the conifers received 19 egg masses, the birches 2, and the chicken wire none.

Eggs containing well developed embryos were first noticed on May 10. No new egg deposits were found after May 17, and all eggs were hatched by May 29. Newly hatched yellow perch were about 0.3 inch in total length. When they reached a length of about 0.6 inch they appeared near the surface in schools of a few to several hundred. These schools appeared over the spawning areas 3 to 6 feet deep, and moved in short spurts which rippled the surface of the water. Schools of fry were first seen on June 12, 1952, in Lower Thompson Lake, and on June 29, 1953, in Middle Thompson Lake. On July 6, 1952, a large school estimated to have an area of 20 by 300 feet and containing many thousands of fry was observed over the shoal area in Lower Thompson Lake. What was believed to be this same school remained intact for three days. On July 23, 1953, there was observed an almost continuous band of yellow perch fry estimated to be approximately four feet wide and extending nearly a mile along the margin of Middle Thompson Lake. On the following day this school had dispersed into the littoral vegetation.

Cutthroat trout.—A nearly ripe (13.2-inch) female cutthroat trout was caught in Lower Thompson Lake on April 16, 1953. On May 7, what was presumed to be a pair of spawning cutthroat trout was observed on a small riffle about three miles up Davis Creek, a tributary to Middle Thomp-

son Lake. One was captured; a ripe male 13.7 inches in total length. Eleven cutthroat trout were seen in this area on April 17 and 18. They were estimated to average about 13 inches long. In the previous year on July 29, a census was taken in a 150-foot section of this area by the electric shock method and 140 cutthroat trout averaging 3.8 inches in total length were captured. No other species were found. From May 21 to June 11, 1953, 21 adult cutthroat trout were removed from a sucker trap at the mouth of Boiling Springs Creek, a tributary to Lower Thompson Lake. These were spent spawners and averaged approximately 13 inches long. On May 16, 1953, numerous fingerling trout were seen approximately one mile up Boiling Springs Creek and on June 17 and 18, about 25 to 50 fingerling trout were observed in the vicinity of the sucker trap. They disappeared from this area on June 19. No trout fry or young-of-the-year were found in the lakes.

During May, 1953, schools of approximately 20 to 70 suckers, either Columbia large scale suckers or longnose suckers or both, were seen in the spawning area used by the perch. Smaller schools of squawfish were here also. No aggressive behavior on the part of one species toward another was observed. Suckers were trapped in the tributary streams beginning May 20, 1953. The largest number was trapped on June 2, after which their number declined. Ripe squawfish were caught in the lake near the stream mouths during this period but were never taken in the traps.

No apparent competition for spawning sites between the yellow perch, cutthroat trout or any of the other fishes was found in Thompson Lakes. Yellow perch eggs were distributed very widely over the entire shoal area. Cutthroat trout undoubtedly confine their spawning to suitable areas of the tributary streams.

AGE AND GROWTH

Yellow perch.—Scale samples from 150 yellow perch were taken during the study period. Age was determined by the usual method and calculations assumed a straight line relationship between the length of scale and length of fish (Table 2). The average calculated mean total length in inches for the year classes I through V were: 1.9, 3.4, 4.4, 5.6, 6.6. The average total length of 900 yellow perch taken by hook and line was 6.2 inches.

The grand average of 3,200 fish captured by all means (angling, gill nets, poison) was 6.4 inches, and only one percent was over 7.5 inches. There is no doubt that this population is slow growing and stunted. Carlander (1950), Hile (1942), and Eschmeyer (1938), in their studies of yellow perch, report few instances of such poor growth.

Cutthroat trout.—Scale samples of 41 cutthroat trout caught by trolling in Middle and Lower Thompson Lakes during the summer of 1953 were analyzed. Calculations assumed a straight line relationship between the length of scale and that of fish (Table 3). The average calculated mean total lengths in inches for the year classes I through IV were: 5.1, 7.8, 10.3, 12.5. The largest fish captured was 23.7 inches in total length, and the average of all cutthroat trout taken was 10.6 inches. This growth is as

TABLE 2.—Mean total lengths and annual length increments (inches) calculated from scales of yellow perch at Lower Thompson Lake, 1952 and 1953

Age group	Number of fish	Length at capture	Calculated total length at end of year of life				
			1	2	3	4	5
I.....	35	2.1	1.8	...	...	...	...
II.....	30	3.5	2.0	3.6	...	...	...
III.....	11	4.4	1.9	3.2	4.3	...	...
IV.....	32	5.8	1.8	3.2	4.4	5.6	...
V.....	42	6.7	2.0	3.3	4.5	5.6	6.6
Average length.....			1.9	3.4	4.4	5.6	6.6
Increment.....			1.9	1.5	1.0	1.1	1.0

TABLE 3.—Mean total lengths and annual length increments (inches) calculated from scales of cutthroat trout at Middle Thompson Lake, 1953

Age group	Number of fish	Length at capture	Calculated total length at end of year of life			
			1	2	3	4
I.....	6	5.6	5.3	...	...	...
II.....	18	8.2	4.9	7.7	...	...
III.....	10	11.0	4.9	7.7	10.4	...
IV.....	7	14.3	5.3	7.9	10.3	12.5
Average length.....			5.1	7.8	10.3	12.5
Increment.....			5.1	2.7	2.5	2.2

good or better than that found for other lakes within the drainage, and only slightly less than that reported by Calhoun (1944) in Blue Lake, California.

FOOD RELATIONSHIPS

A total of 900 yellow perch stomachs were examined from specimens collected by hook and line in the areas of greatest adult concentration in Lower Thompson Lake. A sample of 50 fish was taken every 10 days during the period from June to September in 1952, and from May to September in 1953. Captured fish were preserved immediately in formalin and stomach analyses were made at a later time. The stomachs of 83 cutthroat trout were examined at the time of capture. Specimens were taken by trolling in the Middle and Lower Thompson Lakes during the summers of 1952 and 1953.

Only those food items occurring in more than one percent of the specimens were considered. Ninety percent of the yellow perch and 98 percent of the cutthroat trout had eaten some identifiable food organism. Small fish were eaten by 2 percent of the yellow perch and by 40 percent of the cutthroat trout. Yellow perch fry made up 99 percent of these while the remaining one percent consisted of sucker fry and unidentified fish. The maximum number of yellow perch fry found in cutthroat trout stomachs was 21, with an average of 7.5. The smallest cutthroat trout containing

these fry was 6.5 inches in total length and the largest specimen contained three yellow perch and one sunfish all of which were more than 4 inches in length.

Immature aquatic insects were present in 28 percent and adults in 4 percent of the yellow perch stomachs. Cutthroat trout had immature aquatic insects in 24 percent and adults in 43 percent of their stomachs. About one-half of the aquatic insects were dipterans. Damselflies were second in abundance and mayflies third. Yellow perch apparently showed preference for immature forms while the cutthroat trout ate more adults. Crustacea (*Daphnia*, *Leptodora*, and *Gammarus*) were found in 82 percent of the yellow perch stomachs and in 23 percent of the cutthroat trout. Snails appeared in only two percent of the yellow perch stomachs and in none of the cutthroat trout.

Moffett and Hunt (1943) reported *Perca flavescens* showed a change in diet from plankton and insects to forage fish after reaching about five inches in length. Allen (1935) had previously recognized this for *Perca fluviatilis*. The yellow perch in Lower Thompson Lake showed no marked shift to a diet of fish since only two percent had fish in their stomachs.

The stomach contents of mountain whitefish and kokanee was exclusively plankton. Thirty suckers taken from tributary streams had empty stomachs while 25 specimens captured in the lake contained only detritus and no recognizable food items.

FISH DISTRIBUTION

Experimental gillnets of graded meshes and trolling were used to determine fish distribution. Gillnet sets were made in Lower Thompson Lake during the periods from June to August 1952, and from March to July 1953. These were of 24-hours duration and were made in the following areas (Table 4): 26 sets in deep water (35 to 70 feet), 22 on open shoals (5 to 10 feet), and 24 in weed beds (10 to 15 feet). Yellow perch were caught predominantly in deep water in March and April. Beginning April 29, 1953, heavy catches were made in shoal and weed bed areas in Lower Thompson Lake and continued throughout the summer. Cutthroat trout were never taken by gillnets in deep water or in the open shoal areas. Three specimens were captured in the weed beds in April.

Additional information on distribution was secured by 28 gillnet sets made over deep water. In this area, surface catches of kokanee and cutthroat trout were common during May, and gradually declined until June 10, when the last kokanee was caught. Trolling catches of kokanee and cutthroat trout also declined in June. Floating gillnets were set from the surface or hung from floats to a depth of 30 feet and failed to catch any of these fish during July and August.

EXPERIMENT TO REDUCE THE NUMBERS OF YELLOW PERCH

Schools of yellow perch fry along the shoals were treated with poison (Derris root or Fish-Tox) using an aqueous solution and power pump or towing the sack of the dry poison behind the boat. The towed sack method

TABLE 4.—*Catch of 72 gill-net sets from Lower Thompson Lake during the summers of 1952 and 1953*

[Expressed as catch per gill-net day for species and depth range]

Species	Depth range (feet)	Number of fish caught per gill-net lift		
		March-April	May-June	July-August
Yellow perch.....	35-70	13	8	3
	10-15	10	46	11
	5-10	8	19	6
Cutthroat trout.....	35-70	0	0	0
	10-15	1	0	0
	5-10	0	0	0
Mountain whitefish.....	35-70	7	8	8
	10-15	2	7	3
	5-10	1	0	3
Suckers ¹	35-70	2	2	3
	10-15	6	7	1
	5-10	11	6	3

¹ Longnose sucker and Columbia large scale sucker

disturbed the perch too much to be effective and was discontinued. A tank of solution and a power pump was carried by boat to a position out beyond (lakeward) a school of yellow perch fry. Poison was introduced slightly below the surface in a line parallel to the school of fry. When this barrier of poison was complete the entire area containing fry was sprayed. The minimum amount of poison necessary to get good results in Thompson Lakes was about 8 parts per million of Derris root (5 percent rotenone) or 4 parts per million of Fish-Tox for the immediate areas treated. These high concentrations were necessary to maintain effective levels because of dilution by surrounding water. Fifty pounds of Fish-Tox or 100 pounds of Derris root was sufficient to treat about 1,000 feet of lake margin.

Yellow perch fry usually showed distress within 15 minutes. Although some fish swam through the poison barrier out into clear water most of these died. Dead fry were seen as far as 500 feet from the toxic area. Practically all of the fish in these schools treated were destroyed.

A method was developed for poisoning schools of adult yellow perch. A concentrated solution of Derris root or Fish-Tox was taken by boat to the poison area. The boat was anchored and bait (chopped fish or hamburger) was distributed until a large number of yellow perch had accumulated in the area. Then poison was poured gently into the water over the school of yellow perch. This solution was poured also into the wake of the boat as it slowly circled the yellow perch concentration. Ten pounds of Derris root or 5 pounds of Fish-Tox was sufficient to kill yellow perch in a 100-foot circle over 15 feet of water. Approximately one-half of the solution was used in the baited area and the other half to form the barrier.

The kill of fish in the treated area was almost complete. In 1940, Green-

bank experimented with selective fish poisoning and Swingle (1953) evaluated partial poisoning on known populations of bluegills and largemouth bass in small ponds. He concluded that this was effective in eliminating fish of small or intermediate size. It is believed that intensive partial poisoning in Thompson Lakes would be effective in reducing the yellow perch population.

SUGGESTED MANAGEMENT RECOMMENDATIONS

Total poisoning of the entire Thompson Lake chain is not economically feasible. During the spring months yellow perch are concentrated on the shoal areas and kokanee and cutthroat trout are in deep water. Partial poisoning along the lake margins and in the bays at this time should be effective in reducing the yellow perch population. The hope of such a program should be to reduce the yellow perch population to a level where this species will show good growth and attain useful size. Such a reduction should also make conditions more favorable for an increase in the number of salmonids. A combination method of poisoning yellow perch fry and baiting and poisoning the larger perch is recommended for Lower Thompson Lake. This should be initiated about June 20 and be continued as long as concentrations of yellow perch are found. It is believed that with further study an effective method might be developed for the reduction of yellow perch by concentration and destruction of spawn. An age and growth study should be made at the end of the first year to check the effectiveness of this program.

As soon as the treated areas in Lower Thompson Lake are non-toxic, cutthroat trout fry at the rate of 300 or more per acre should be planted along the littoral zone.

Since the cutthroat trout are known to feed rather extensively on yellow perch fry it is recommended that heavy plantings of cutthroat trout, 7 inches long or over be made in Middle Thompson Lake. To prevent fish movement between Middle and Lower Thompson Lake a screen barrier should be installed in the connecting channel.

A careful check should be made on all plantings in both lakes by creel census and gill netting.

Fishermen should be encouraged to harvest yellow perch by furnishing them with all information on effective fishing methods and perch distribution. Means should also be developed whereby the mountain whitefish, which is relatively abundant and very poorly utilized, can be harvested.

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EARLY LIFE HISTORY OF THE YELLOW PERCH,
PERCA FLAVESCENS (MITCHILL), IN THE RED LAKES,
MINNESOTA¹

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ABSTRACT

The early life history of the yellow perch, an important commercial species in the Red Lakes, Minnesota, has been studied with special reference to length at scale formation, growth rate during first season of life, and food habits as they relate to growth and survival. Scales are fully imbricated in the area of 12th to 14th lateral line scales at 24 millimeters total length. There is a wide annual variation in first season's growth which is not correlated with growth in older fish. Body-scale relationship is rectilinear from 24 to 280 millimeters. Length-weight relationship during the first year is expressed by the equation $W = 0.6198 \times 10^{-5} L^{3.1251}$ which is very similar to that describing the relationship in later years. Stomach analysis indicates food is primarily plankton but in some seasons fish may be strongly dependent on bottom forms. Variations in food availability appear to be associated with changes in growth and may have a major influence on survival.

INTRODUCTION

The yellow perch, *Perca flavescens* (Mitchill), is an important commercial species in the Red Lakes, Minnesota (Smith and Krefting, 1954). Six years' investigation of the fishery has shown that fluctuations in abundance are caused primarily by differences in strength of individual year classes. To evaluate the factors influencing these changes a series of studies on the early life history of the perch and other associated species has been carried on. From 1952 through 1954 particular attention has been given to the growth rates, food relationships, and mortality of perch during the first season of life. In the present paper first-year growth in length and weight, food habits, and size of fish at time of scale formation have been described together with certain implications of these data in connection with the problems of year-class strength. Mortality rates during the first year will be discussed in a subsequent paper dealing with interrelations between yellow perch and associated fish species.

The work has been carried on in cooperation with the U. S. Office of Indian Affairs and with the assistance of the Great Lakes Fishery Investigations, U. S. Fish and Wildlife Service.

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METHODS AND MATERIALS

Field work for this study was carried on, July 8 to August 14, 1952, June 18 to October 2, 1953, and July 22 to October 9, 1954. Information on growth and age structure of the population was available from other studies in progress at the University of Minnesota.²

Small-fish collections were made with a $\frac{1}{4}$ -inch-mesh bag-seine, which was lined with $\frac{1}{8}$ -inch-mesh marquisette, until the perch were large enough to be held by the $\frac{1}{4}$ -inch mesh of the seine. The liner was then removed. With the liner in place it was possible to take yellow perch as small as 11 millimeters in length. Shore collections of young perch were supplemented by collections made with a beam trawl constructed from $\frac{1}{4}$ -inch-mesh webbing.

Quantitative plankton samples were taken in 1953 with a 10-inch diameter, 60-mesh-to-the-inch hand plankton net, and with an 18-inch diameter metered tow net, using both 26-mesh and 80-mesh nets, for tows of 400 to 650 cubic feet each. Daily maximum and minimum air temperatures were recorded together with estimates of wind direction and velocity. Water temperatures were observed during sampling periods.

All fish were counted in the smaller samples and a random subsample of at least 100 fish was measured when the sample was larger than that number. Length measurements were made to the nearest millimeter on 419 young-of-the-year perch collected in 1952, on 3,155 taken in 1953, and on 3,490 caught in 1954. Length-weight relationship was determined from 198 fish weighed to the nearest 0.005 gram on a torsion balance. All measurements and weights were taken from fish preserved in 10-percent formalin.

Stomach analyses were made on 110 first-season perch taken in 1952, 244 collected in 1953, and 30 taken in 1954. The stomach was removed from the fish and dissected under a X45 dissecting microscope. Counts of all organisms were made in a Sedgwick-Rafter cell, and exceptionally large or small size of individuals was noted. Zooplankton counts of plankton samples were made in the same manner. The pattern of scale formation was determined by staining whole specimens, which had been preserved in formaldehyde, with alizarin red in 0.02 normal KOH solution (Ward and Leonard, 1952).

GROWTH OF YOUNG PERCH

Growth in length.—To determine the rate of growth during the first summer of life, mean lengths of fish taken throughout the season were plotted against time. Straight lines calculated by the method of least squares were fitted to the means of each year's samples for the period before August 20. The length at the end of the season for 1952 was determined from back calculations made on the scales of I-group perch taken in 1953, but samples were collected in early October in 1953 and 1954 to determine the end points for those seasons. Samples were secured from four

² Minnesota Agricultural Experiment Station Project No. 167-2217.

widely separated areas of the lake and are believed to be representative of the entire population.

In 1952, when the first sample was taken on July 8 and the last on August 14 (Table 1), the total length increased from 33.6 millimeters to 46.7 millimeters during this period. The slope of the curve indicates an average growth of 0.35 millimeter per day (Fig. 1). In 1953 samples were collected between June 22 and August 18, and on October 2 (Table 2). Total length increased from 19.0 millimeters on the first date to 61.4 millimeters on August 18, an average growth of 0.73 millimeter per day. In 1954 samples were taken only from July 22 to August 19, and again on

TABLE 1.—Average lengths of O-group yellow perch from Lower Red Lake on various dates in 1952

Date	Number of fish	Mean length (millimeters)	Corresponding length on calculated line
July 8.....	107	32.9	33.6
July 17.....	73	38.5	36.8
July 24.....	87	38.2	39.3
August 6.....	54	44.3	43.9
August 14.....	59	46.5	46.7
October 2 ¹	25	55.4	....

¹ Back calculations were made from I-group fish taken in June 1953. The date, October 2, was chosen only to correspond to the last observation in 1953

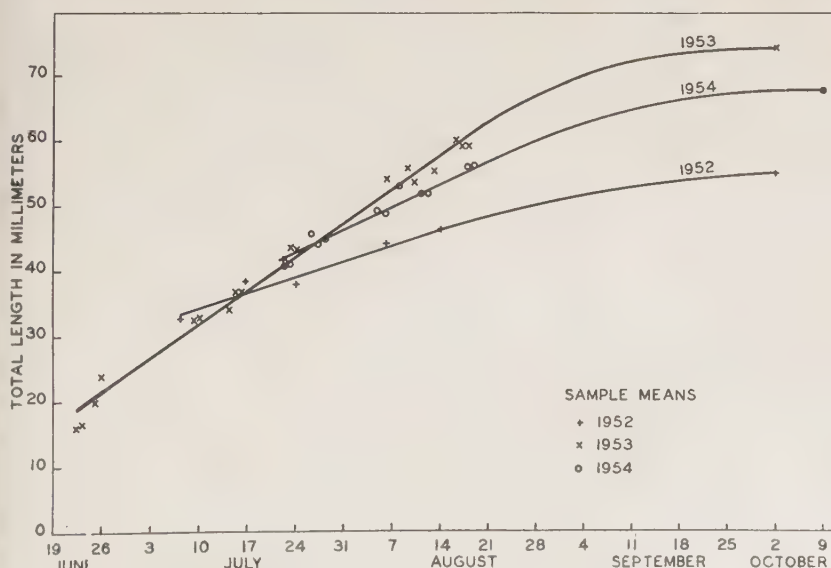


FIGURE 1.—Growth in length of yellow perch during the first season of life—1952, 1953, 1954.

TABLE 2. — Average lengths of O-group yellow perch from Lower Red Lake on various dates in 1953

Date	Number of fish	Mean length (millimeters)	Corresponding length on calculated line
June 22.....	44	16.2	19.0
June 23.....	7	16.6	19.7
June 25.....	36	20.2	21.1
June 26.....	92	24.2	21.9
July 9.....	300	32.6	31.4
July 10.....	175	33.2	32.1
July 14.....	125	34.3	35.0
July 15.....	200	37.0	35.8
July 16.....	200	37.0	36.5
July 22.....	100	42.2	40.9
July 23.....	233	43.8	41.6
July 24.....	200	43.6	42.4
August 6.....	157	54.4	51.9
August 9.....	90	56.0	54.1
August 10.....	250	54.0	54.8
August 11.....	200	56.1	55.5
August 13.....	163	55.6	57.0
August 16.....	142	60.4	59.2
August 17.....	121	59.4	59.9
August 18.....	205	59.4	60.6
October 2.....	110	74.6	....

October 9 (Table 3). From July 22 to August 19, length increased from 41.9 millimeters to 55.9 millimeters, an average of 0.53 millimeter per day.

Meek (1916) gave the length at hatching of the European perch, *Perca fluviatilis* Linnaeus, as 5 millimeters, and Fish (1932) described a recently hatched yellow perch that was 5.6 millimeters long. Back extrapolation of the linear growth curves for 3 years to 5 millimeters would indicate hatching on April 17, June 5, and May 18 for 1952, 1953, and 1954, respectively. Since the ice did not melt off the Red Lakes until about May 1 in 1952 and 1953, and May 15 in 1954, it seems doubtful that a linear backward extrapolation of the growth curves gives a reasonable representation of early summer's growth except possibly in 1953. Probably the early summer's growth was curvilinear and declining in 1952 and 1954.

GROWTH IN LENGTH AND SCALE FORMATION OF PERCH IN 1953

A number of studies have shown that scales of fish do not form simultaneously over the body but that scalation proceeds according to a pattern peculiar to the species (Potter, 1924; Everhart, 1949; Brown and Bailey, 1952; Ward and Leonard, 1952). In the present study the pattern of scale formation in the yellow perch from the Red Lakes has been worked out from collections made in 1953 (Fig. 2). Scale pockets first appear on the caudal peduncle when the fish is about 20 millimeters long. Scalation proceeds anteriorly along the lateral line, and at the same time dorso-ventrally from the lateral line. By the time the fish is approximately 24 millimeters long, the first scales are fully imbricated in the region immediately ventral to the 12th to 14th lateral-line scales. Scalation continues in this

manner until the fish is fully scaled at about 36 or 37 millimeters. The nape and the anterior portion of the belly are the last regions to become completely scaled. Examination of fish of the same size taken on different dates revealed no systematic variation in amount of scalation. Size rather than age determines the amount of scalation.

The body-scale relationship of older yellow perch from Red Lake as determined from the second row of scales ventral to the 12th to 14th lateral-

TABLE 3. — *Average lengths of O-group yellow perch from Lower Red Lake on various dates in 1954*

Date	Number of fish	Mean length (millimeters)	Corresponding length on calculated line
July 22.....	300	41.1	41.9
July 23.....	300	41.4	42.5
July 26.....	191	46.1	44.1
July 27.....	366	44.4	44.6
July 28.....	200	45.2	45.1
August 5.....	16	49.5	49.4
August 6.....	311	49.0	49.9
August 8.....	267	53.5	51.0
August 11.....	200	52.2	52.6
August 12.....	298	52.1	53.1
August 18.....	474	56.5	56.3
August 19.....	296	56.4	56.8
October 9.....	271	68.1	....

line scales was described satisfactorily by a straight line crossing the body-total length axis at 23 millimeters. On the basis of this regression and the data for first-season fish, it is evident that the body-scale relationship of perch in this population is rectilinear in the range from 24 to 280 millimeters. Back calculations of length from the first annulus of older fish should, therefore, give correct values for the total length at the end of the first growing season.

The age of the yellow perch at the time of scale formation could not be determined exactly. Since scalation takes place over a period of time, the size or age at scale formation must be related to a given area of the body. Since June 5 is the best estimate that can be made of the time of hatching in 1953, the young perch were about 3 to 4 weeks old at the time scales were fully imbricated in the region immediately below the 12th to 14th lateral-line scales.

COMPARISON OF FIRST-SEASON'S GROWTH IN VARIOUS YEARS

Estimates of first-season's growth for the years 1944 through 1952 were made from back calculations of length at the first annulus on fish taken in experimental gill nets from 1949 through 1953 (Table 4, Fig. 3). During this period first-year increment ranged from 54.4 to 74.6 millimeters and averaged 62.9 millimeters.

Hile (1941) found that first-year's growth of rock bass in Nebish Lake,

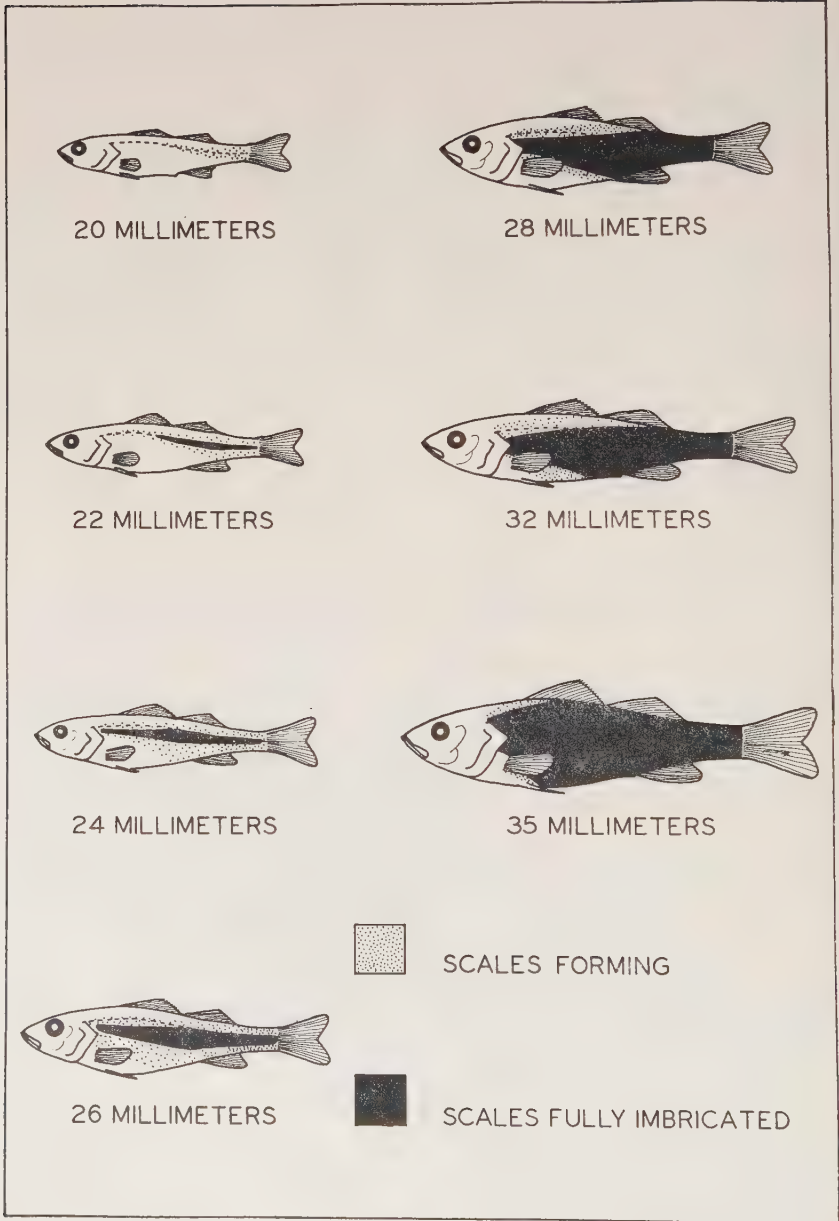


FIGURE 2.—Scale formation in 0-group yellow perch.

TABLE 4. — *Length at first annulus and fluctuations of first-year and later growth of yellow perch in Lower Red Lake*

Year	Number of fish	Mean length of young (millimeters)	Percentage deviation from mean growth	
			Young-of-year	Older fish
1944.....	160	62.2	- 0.11	+12.55
1945.....	127	62.2	- 0.11	+ 3.12
1946.....	440	67.3	+ 6.99	+11.03
1947.....	396	61.2	- 2.70	+ 6.67
1948.....	136	62.0	- 0.14	+ 4.98
1949.....	154	62.7	- 0.03	-11.09
1950.....	24	54.4	-13.51	-45.52
1951.....	44	62.2	- 0.11	+13.27
1952.....	25	55.4	-11.92	+ 4.96
1953.....	110	74.6	+18.60	.....
1954.....	186	68.1	+ 8.27	.....

Wisconsin, was not consistent with growth of older fish in the same year, but in Saginaw Bay (Hile, 1954) he noted that there was a significant correlation between growth of O-group walleyes and that of older fish. In Red Lakes perch the coefficient of correlation between first-year's growth and the growth of older fish in the same year (expressed as percentage deviation from the mean) was 0.09 for the period 1944–1952. It appears then,

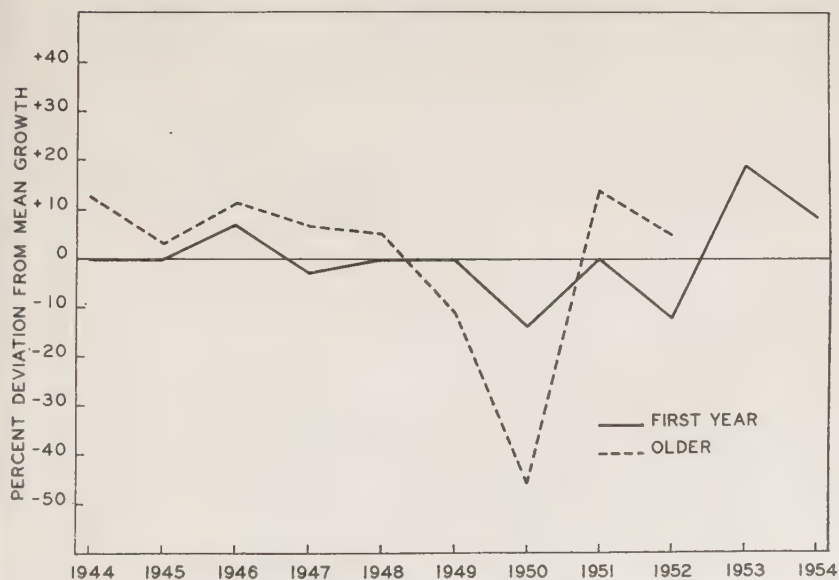


FIGURE 3.—Change of growth increment in young-of-year perch and older fish expressed as percentage deviation of mean growth, 1944–1954

that growth of juvenile perch is either only partially dependent on the same factors as growth in the older fish, or is dependent on different factors altogether.

RELATION BETWEEN GROWTH AND YEAR-CLASS STRENGTHS

The relationship between first-year growth and year-class strength was studied to determine whether conditions suitable for good growth might also be conducive to high survival.

Since available data on year-class strength of perch in the Red Lakes are not adequate to assign a numerical rating to the various years, a relative scale of strength for each year of the period 1944–1951 was derived from age compositions of commercial and experimental gill-net catches. The first year's growth in each of the various years was assigned to a similar scale for comparison with the apparent brood strength in that year (Table 5). It is apparent that no strong association between year-class

TABLE 5. — *Estimates of year-class strengths and quality of growth in the first year of life of yellow perch in Lower Red Lake, 1944–1951*

Year	Year-class strength	Growth in first season
1944.....	Strong	Medium
1945.....	Weak	Medium
1946.....	Very strong	Good
1947.....	Very strong	Poor
1948.....	Weak	Medium
1949.....	Moderate	Medium
1950.....	Very weak	Very poor
1951.....	Moderate	Medium

strength and growth existed. For example, the 1946 and 1947 year classes are known to have produced all-time record commercial catches for 3 consecutive years, but first season's growth was good in 1946 and poor in 1947.

GROWTH IN WEIGHT

The length-weight relationship of 198 first-season perch taken during 1953 was described satisfactorily by the equation

$$W = 0.6198 \times 10^{-5} L^{3.1251}$$

(W = weight in grams, L = total length in millimeters). A similar curve with an exponent of 3.1227 fitted empirical weights and measurements very well for Red Lakes perch in the 76- to 305-millimeter range. It appears that the length-weight relationship does not change appreciably throughout life, and that yellow perch become progressively plumper throughout life.

By applying this relationship to the growth-in-length curve for the 1953 season it was determined that average individual weight increases slowly until about the middle of July, increases rapidly until early September, then

increases more slowly until late September or early October (Table 6, Fig. 4). The average weight of O-group perch at the end of the 1953 growing season was 4.4 grams. Provided that the length-weight relationship does not vary greatly from year to year, average weights were only 1.7 grams at the end of the 1952 season and 2.9 grams at the end of the 1954 season.

TABLE 6. — *Growth in weight of O-group perch from Lower Red Lake during the summer of 1953*

Date	Weight (grams)	Increase (grams)	Percentage increase
June 19.....	0.04	...	...
June 26.....	0.09	0.05	125.0
July 3.....	0.18	0.09	100.0
July 10.....	0.31	0.13	72.2
July 17.....	0.50	0.19	61.3
July 24.....	0.76	0.26	52.0
July 31.....	1.11	0.35	46.1
August 7.....	1.53	0.42	37.8
August 14.....	2.03	0.50	32.7
August 21.....	2.63	0.61	30.0
August 28.....	3.21	0.57	21.6
September 4.....	3.70	0.49	15.3
September 11.....	4.05	0.35	9.5
September 18.....	4.30	0.25	6.2
September 25.....	4.41	0.11	2.6
October 2.....	4.41	0.00	0.0

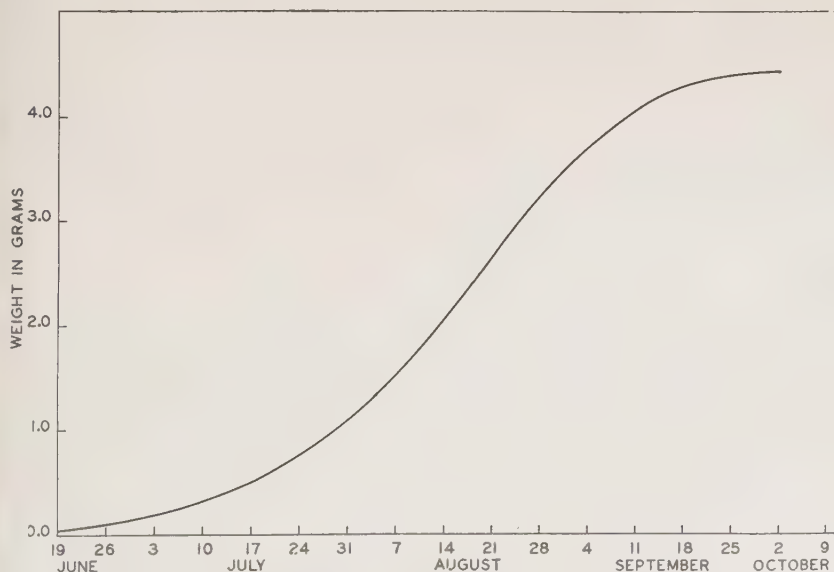


FIGURE 4.—Growth in weight of yellow perch during the first season of life in Red Lakes, Minnesota.

FOOD OF THE YOUNG PERCH

The food of yellow perch has been reported from many sources, but the relation that food bears to growth and survival of the young has not been well defined. Clemens *et al.* (1924) found that Lake Nipigon perch less than 40 millimeters long fed on plankton. In fish from 40 to 80 millimeters in length insects and fish became increasingly important and beyond 80 millimeters, plankton was negligible. Ewers (1933) reported that 94.3 percent of the food of Lake Erie perch between 14 and 79 millimeters long consisted of Copepoda and Cladocera and that food-take varied with changes in the plankton. Very young perch from a number of northeastern Wisconsin lakes ate Entomostraca but quickly changed to a diet of small Diptera larvae (Couey, 1935). Many other studies have shown that perch have some preference for larger forms like insect larvae and amphipods, but are not highly selective and will take plankton at any size during the first year of life.

TABLE 7. — Number of stomachs in which various organisms occurred in O-group yellow perch in 1952

Item	Length (millimeters) and number of fish				
	25-29 (1)	30-39 (48)	40-49 (43)	50-59 (18)	60-69 (5)
<i>Cyclops</i>	—	6	1	—	—
<i>Diaptomus</i>	—	5	4	—	—
<i>Chydorus</i>	—	8	5	—	—
<i>Bosmina</i>	—	11	14	3	—
<i>Holopedium</i>	—	1	9	3	1
<i>Daphnia</i>	—	—	4	—	—
<i>Alona</i>	—	—	3	1	—
<i>Leptodora</i>	—	2	13	—	—
<i>Hyaella</i>	—	7	23	11	5
Chironomid larvae.....	—	4	20	12	5
Dragonfly larvae.....	—	—	1	1	—
Mayfly larvae.....	—	2	1	—	—
Corixidae.....	—	2	1	—	—
Hydracarina.....	—	2	1	—	—
Coleoptera larvae.....	—	—	1	—	1
Unidentified insects.....	—	4	1	1	—
Fish eggs.....	—	—	1	—	—
Empty.....	1	21	3	—	—

During the present study an attempt has been made to evaluate annual fluctuations in food utilization and their possible relationships to growth rate and survival. In 1952 young perch fed principally on small Cladocera and Copepoda until they were more than 40 millimeters long (Table 7). As many as a thousand *Bosmina* were found in some stomachs. In the 40- to 49-millimeter range *Leptodora*, *Hyaella*, chironomid larvae, and other insect larvae comprised the bulk of the food, but considerable numbers of small Cladocera were also taken. Fish larger than 50 millimeters ate *Hyaella* and chironomid larvae almost to the exclusion of other forms.

During 1953 small- and medium-sized Cladocera and Copepoda were the

principal items until the yellow perch had reached a length of about 30 millimeters (Table 8). *Bosmina* was found in only 5 of 36 stomachs and was scarce in those. Beyond 30 millimeters *Diaphanosoma*, *Sida*, *Daphnia*, *Eurycercus*, and *Leptodora* were the most commonly eaten organisms and comprised the bulk of the food. Beyond 50 millimeters many stomachs contained *Hyalella* or chironomid larvae, but in only a few did they comprise a large portion of the contents. Since the occurrence of food items was generally similar to the abundance of these forms in the plankton throughout the summer, there was apparently no significant selection by the fish. Although there are no data on relative availability of food in 1952 and 1953, the fact that *Leptodora* was the only organism that formed an important part of the food in both years suggests a major change in the food supply.

TABLE 8. — Number of stomachs in which various organisms occurred in O-group yellow perch in 1953

Item	Length (millimeters) and number of fish							
	10-19 (16)	20-29 (20)	30-39 (56)	40-49 (43)	50-59 (60)	60-69 (23)	70-79 (19)	80-89 (7)
<i>Cyclops</i>	6	2	3	1	7	2	2	—
<i>Diaptomus</i>	4	8	19	24	9	2	2	—
<i>Epischura</i>	—	1	5	6	11	4	3	—
<i>Alona</i>	4	2	—	—	—	—	—	—
<i>Chydorus</i>	5	4	3	2	1	—	1	—
<i>Bosmina</i>	5	—	1	—	—	—	—	—
<i>Diaphanosoma</i>	2	3	8	23	38	11	6	—
<i>Sida</i>	5	2	11	—	12	5	2	—
<i>Daphnia</i>	2	11	41	30	26	7	16	4
<i>Eurycercus</i>	—	1	28	16	23	13	13	6
<i>Leptodora</i>	7	15	21	34	15	7	17	3
<i>Hyalella</i>	—	—	—	2	21	9	3	1
Chironomid larvae.....	—	—	—	1	10	7	1	—
Dragonfly larvae.....	—	—	—	—	1	—	—	1
Mayfly larvae.....	—	—	—	—	—	—	—	2
Unidentified insects.....	—	—	4	—	7	1	—	—
Fish eggs.....	—	—	—	—	3	3	—	—
Empty.....	—	—	—	—	3	—	—	—

The number of stomachs examined in 1954 was small, but it was apparent that *Hyalella* and chironomid larvae comprised the bulk of the food. *Sida* was the only plankton organism of major importance and *Bosmina*, which was very abundant in 1952, was not present in 1954. It appears, therefore, that an appreciable change in the food supply again occurred between 1953 and 1954.

Consideration of stomach analysis of young perch from Red Lakes indicates a wide variation of food utilization in different seasons, which is probably associated with the levels of availability. The incidence of various food items suggests that changes in growth rate of first-year perch are closely associated with changes in availability of food; this factor may also have a major influence on survival.

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MANAGEMENT OF STEELHEAD TROUT IN THE STATE OF WASHINGTON

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ABSTRACT

The increase in the angling for steelhead trout (*Salmo gairdneri irideus*) since the end of World War II caused fishery biologists in the State of Washington to re-evaluate their management policies and to search for a means of building up runs of adult steelhead trout in depleted or heavily fished streams. Experiments were conducted to determine the proper size and time of planting of hatchery-reared steelhead trout to obtain best returns of adults. It was found that the planting of migrant-sized steelhead trout during the normal migration period of wild fish provided the best returns. Runs of adult steelhead trout have been built substantially up by plants of hatchery-reared fish as evidenced by trap returns on planted streams.

Regulations on the fishery for mature and immature steelhead trout have tended to become more liberal on the mature and more stringent on the immature fish. Seasons on adults extend through March and April in many streams having late runs, rather than being ended at the end of February as in the past. Points above which no fishing is allowed are shifted down stream as the fishing season progresses, thus protecting the spawners and allowing fresh-run steelhead trout to be taken. Immature fish are being protected by a July 1 opening on the lower reaches of steelhead trout streams where the migrant-sized fish congregate before moving into salt water. Some rivers have a 10-inch minimum size limit in effect during the entire summer season to protect the immature trout.

INTRODUCTION

The popularity of fishing for steelhead trout in the State of Washington has increased steadily since the end of World War II. The number of steelhead fishermen has increased from 41,000 in the 1948-49 winter steelhead season to 77,300 in the 1952-53 season. The increase in the number of steelhead trout fishermen caused fishery biologists to re-evaluate the management program of the state. The phases of the management program that were unproven required that experiments be conducted to put the entire program in the State on a sound, practical, and paying basis. This management program is divided into two phases; first, the supplementing of runs of steelhead trout by artificial propagation; and second, the maintaining of natural runs by practical management. This paper is an explanation of our management policies and the reasons for them.

THE ARTIFICIAL PROPAGATION OF STEELHEAD TROUT

The first of two phases of the management program for steelhead trout in Washington is the supplementing of depleted runs and runs in heavily-

fished rivers with hatchery-reared fish. The planting of hatchery-reared steelhead trout could not be utilized as a part of the steelhead management program until the proper size of fish at planting time and the best time of planting were determined by a series of marking experiments.

The first marking experiments were conducted in the Samish River, a comparatively short stream flowing into Samish Bay south of Bellingham. The river has two main tributaries, one formed by springs and the other by water from the outlets of Lakes Samish and Cain. An upstream trap for adult fish is located just below the confluence of the two main branches of the river. In May 1948, three groups of steelhead trout were marked and planted in the Samish River. One group totalling 5,100 and ranging from 15 to 31 per pound in size was marked by removing the right ventral fin. The second group totalling 6,180 and averaging 14 to the pound was marked by removing the dorsal and right ventral fins. The third group of 10,695 steelhead trout, averaging 35 per pound, was marked by removing the left ventral (Table 1).

A 0.4-percent return resulted from the first of the above plants, a 0.6-percent return resulted from the second, and a 0.2-percent return resulted from the third. These returns represent total sport fishery and trap counts. It was evident from these experiments that plants of steelhead trout smaller than migrant size were not the answer to the problem of supplementing runs of adults.

In 1949 two groups of steelhead trout were marked and planted in the Samish River. One group totalling 5,000 and averaging 16 to the pound was marked by removing the right ventral and adipose fins and was planted in May. The second group also totalled 5,000, and averaged 27 to the pound. This group was marked by removing the right and left ventral fins, and was planted in June. A 0.8-percent return resulted from the first lot and a 0.4 percent return from the second. These experiments were further proof that planting of small steelhead trout was not the answer to the problems at hand.

In 1950 a series of four marking experiments was conducted. Three of the groups were planted in the early summer to obtain a comparison of the returns of different-sized steelhead trout planted under the same conditions, and the fourth group was planted during the winter to obtain a comparison of returns of summer and winter plants. Details on numbers and sizes of fish and on marks used are given in Table 1.

The steelhead trout averaging 9 to the pound (planted in May) gave a return of 6.4 percent; fish that averaged 12 per pound gave a return of 4.8 percent; and the ones that ran 28 per pound gave a return of 0.3 percent. The return from the December plant (12 per pound) was 1.2 percent. The recaptures from these four groups of steelhead trout proved that the plants of migrant-sized fish produced returns of sufficient magnitude to make stocking of hatchery-reared steelhead feasible. A comparison of returns of steelhead trout of the same size, planted in the early summer and in the winter definitely proved the advantage of spring or early-summer plants over winter plants.

TABLE 1.—The results of the Samish River marking experiment

Year	Month planted	Mark ¹	Number planted	Number per pound	Age (months)	Year of return					Percentage return
						'49-'50	'50-'51	'51-'52	'52-'53	'53-'54	
1948.....	May	RV	5,100	15-31	12	4	6	6	2	...	0.4
do.....	do.	D, RV	6,180	14	12	26	8	2	...	...	0.6
do.....	do.	LV	10,695	35	12	3	7	16	...	...	0.2
1949.....	do.	RV, Ad	5,000	16	13	...	23	16	...	...	0.8
do.....	June	RV, LV	5,000	27	13	...	1	17	2	...	0.4
1950.....	May	LV, Ad	10,926	9	25	...	3	539	152	3	6.4
do.....	June	Ad	8,600	12	13	...	...	202	211	1	4.8
do.....	do.	D, LV	5,300	28	13	...	...	...	11	1	0.2
do.....	December	D	7,195	12	18	...	...	...	73	13	1.2

¹ R=right; L=left; D=dorsal; V=ventral; Ad=adipose

Concurrently with the Samish River marking experiments were those conducted in Chambers Creek. This is a relatively short stream, which flows approximately 6 miles from Lake Steilacoom to Puget Sound. Several spring-fed tributaries maintain a substantial flow during the summer and Lake Steilacoom assists in curbing flood waters during a rainy season. A low dam with fish-trapping facilities is located at tide water and a weir with trapping facilities is situated about $\frac{1}{4}$ mile below Lake Steilacoom. Some steelhead trout spawn in the main creek below the upper trap, and since the lower trap was not operated during the first experiment, many marked fish may have returned undetected.

Chambers Creek was open to trout fishing by juveniles under 16 years of age prior to 1950, but not since that time. Winter fishing for adult steelhead trout has been prohibited for years.

Three lots of steelhead were marked and released into Chambers Creek, one lot in 1949 and two in 1951 (Table 2). The first lot of 3,417 yearling

TABLE 2.—Results of the Chambers Creek marking experiment

Year	Month planted	Mark ¹	Number planted ¹	Number per pound	Returns in year					Total returns	Percentage return
					1950	1951	1952	1953	1954		
1949...	May	RV	3,417	7.5	1	206	23	...	...	230	6.7
1951...	March	RV	7,916	5.6	..	...	44	580	93	717	9.1
1951...	May	LV	7,933	4.4	...	...	37	816	153	1,006	12.7

¹ RV=right ventral; LV=left ventral

steelhead trout averaged 7.5 to the pound and was planted in May 1949. They were subjected to a fishery by juveniles, which undoubtedly affected the number of returning adults. In addition to bias from the fishery on immature fish, the trap was out of operation for 17 days during February 1951 due to flood waters. During this 17-day period, an estimated 45 steelhead trout returned to the stream. This estimate was made after a careful check of the stream after the flood waters receded. The total return from the plant of 3,417 steelhead trout was 230 adults or 6.7 percent.

In February 1951, a pond of 16,000 steelhead trout was divided into two groups, one of which was marked by the removal of the right ventral fin and the other by the removal of the left ventral fin. The 7,916 fish of the right-ventral group was planted in March 1951 at 5.6 to the pound. The other group of 7,933 was planted in May at 4.4 to the pound. These fish were all yearlings.

The March plant gave a return of 9.1 percent and the May plant gave a return of 12.7 percent. It is felt that the percentage return of these two groups of steelhead trout is a minimum figure as many of the adults that returned as "jacks" passed through the trap uncounted.

The plants of marked steelhead trout in Chambers Creek corroborated

the experiments on the Samish River by demonstrating that the planting of migrant-sized fish during the migration period of wild steelhead trout would provide the best returns of adult fish.

In April 1951, a total of 25,000 yearling steelhead trout were planted into Soos Creek, a tributary of the Green River. These fish ranged from 6 to 9 to the pound and were marked by removal of the adipose fin. Soos Creek is a small stream formed by the Little Soos Creek, outlet of Lake Young, and Covington Creek. Soos Creek empties into the Green River near Auburn. An upstream trap is located on the creek.

This plant of 25,000 migrant-sized steelhead trout gave a return of 1,631 adult fish for a 6.5-percent return. This figure is felt to be a minimum as only 35 marks were reported from the sport fishery in the Green River. This river has such an intensive sport fishery for steelhead trout that the true number was probably several times the 35 actually reported.

The results obtained from marking experiments have changed our planting policies considerably. The average weight of steelhead trout planted in the State of Washington has increased steadily in the past few years. The weight of fish planted was 806 per pound in 1940, 24.4 per pound in 1950, and 13.5 per pound in 1953. These average per pound figures include all sizes of steelhead from fry (less than 100 per pound) to migrant-sized fish.

The plants of steelhead trout below migrant size have remained nearly constant during the last two years and will probably vary little in the years to come. These plants are the result of reducing the number of steelhead trout in the hatchery during the summer and fall. To insure adequate numbers of fish for rearing in hatchery ponds, excess eggs are taken each spring and an excess of fry held in the ponds at the hatcheries. The numbers of steelhead trout in the ponds are cut each summer and fall to permit maximum growth of the fish held for spring release. The smallest steelhead trout are planted each fall; most of them would not reach migrant size by the following spring.

The State of Washington now has two hatcheries producing only steelhead trout, as well as several others that rear them in two or three ponds for local planting. The number of ponds devoted to rearing steelhead trout is regulated by the number of rainbow and cutthroat trout fingerlings needed in each area each year.

The planting of migrant-sized steelhead trout in our streams has definitely built up our runs of adult fish. It is too early to evaluate positively the success of our planting in larger streams from a sport-catch figure, but another year or two should give us the complete story. Coincidental with our first large plantings of migrant-sized steelhead trout was a normal upturn in runs in nearly all of our rivers. Many of our unplanted rivers had large increases in runs of adult steelhead trout during the 1951-52 season as did our planted rivers. The percentage increase in the run was normally greater in our planted streams than in our unplanted waters. However, the sustained high catch of the planted streams should

indicate the success of our planting program. The streams that are not planted should experience the normal fluctuations of a natural run.

Evidence obtained from trap returns on streams planted with migrant-sized steelhead trout have definitely shown the value of our plants. In all streams that have a trap and were planted with migrant-sized steelhead trout, the increase in the total return of adults through the trap has coincided with our plantings (Table 3). Returns in May Creek, Soos Creek, Bingham Creek, and the Samish River all increased as a result of planting with migrant-sized fish. The single exception was offered by the returns through the trap on the Samish River in 1953. The large return in

TABLE 3.—*Trap returns of adult steelhead trout on various streams before and after the planting of migrant-sized steelhead*

(Plants made 2 years previously in parentheses below the year of return)

River	Year					
	1949	1950	1951	1952	1953	1954
Bingham Creek.....	...	...	236	203	1,334 (32,695)	1,182 (29,401)
May Creek.....	87	38	61	392	714 (27,672)	190
Samish River.....	503	521	800	3,300 (24,619)	14,317 (1,500)	2,334 (14,154)
Soos Creek.....	551	401	224	213	2,829 (25,274)	969

¹ Plants of 36,000 steelhead trout at 160 to 500 per pound made in Samish and Cain Lakes in the fall of 1949 would be included in the returns for 1953. Both of these lakes have outlets flowing into the Samish River

1953 was due to a plant of 36,000 steelhead trout from 160 to 500 per pound made in Samish and Cain lakes in the fall and winter of 1949. Both of these lakes have outlets flowing into the Samish River. These young steelhead trout reached migrant size in the spring of 1951. In May Creek and Soos Creek the cessation of plants in 1952 brought a sharp decline in runs of adult steelhead through the traps in 1954.

A method of building up runs of steelhead trout that has not been completely explored as yet is the planting of fish of less than migrant size into lakes that have outlets flowing into a river system. Marking experiments proved the ineffectiveness of planting such small fish in streams. It is believed that these small steelhead failed to provide returns because of the lack of sufficient food in the streams for the planted fish to reach migrant size in competition with existing populations. However, small steelhead trout planted in lakes with outlets flowing into a river system could easily find the necessary rearing area and the food lacking in the streams.

An experiment to obtain factual data on the results from planting of small steelhead trout in a lake with an outlet flowing into a river system was conducted in Grandy Lake, tributary to the Skagit River. Due to the

lack of information on returns of adults from this planting, nothing conclusive could be determined. There was indication, however, that the plant was valuable. Ten thousand marked steelhead trout were planted in the lake at 83 to the pound, and 10,000 marked steelhead of the same size were planted in the outlet of the lake. A number of the lake-planted fish were caught in the sport fishery of the lake the spring following the plant, but they soon disappeared from the catch.

During the winter of 1951-52 a check made of fishermen employing guides on the Skagit River showed the catch of the lake-planted steelhead trout exceeded many times the catch of the stream-planted fish. Trap returns for the year in Grandy Creek showed a return of 69 adults from the lake-planted steelhead trout to 3 for the stream-planted individuals.

Further evidence of the possible success of lake planting of young steelhead trout is shown by the returns of adults to the Samish River trap in 1953. The stream plant in 1951 consisted of only 1,500 migrant-sized steelhead, which could not possibly account for the large number of adults coming through the trap. It is also impossible to believe that the fish naturally reared in the river could account for the large number returning to the trap in 1953. In the fall and winter of 1949, 26,691 steelhead trout at 160 to 180 to the pound were planted in Samish Lake and 9,234 at 500 to the pound were planted in Cain Lake. Both of these lakes have outlets flowing into the Samish River. These young fish could not possibly have reached migratory size by the spring of 1950, but rather did so in the spring of 1951. The return of the migrants moving out of the lakes in 1951 would account for the large number of adults in 1953.

Further experiments will be conducted on this phase of management to determine the actual value of the lake planting of young steelhead trout. This procedure could offer unlimited possibilities. The need for definite amounts of hatchery space for the rearing of other trout for our lakes limits the space for the rearing of steelhead. Utilization of lakes for the rearing of migrants would appear to be the only source for expansion of the steelhead rearing program. The setting aside of certain lakes for the rearing of steelhead trout, or the construction of impoundments above falls in streams could easily build up our runs of adult steelhead at a minimum of cost. If the body of water was of sufficient size to rear large numbers of migrants, it might be feasible to trap the migrants and transplant them to other rivers. The cost of such a program would be small. It is planned to use two large lakes in Washington for rearing steelhead trout by 1955.

MANAGEMENT BY REGULATIONS

The second phase of our steelhead management program is the protection of the natural runs of steelhead trout in the streams of Washington. The most important means of carrying out this phase are regulations. These regulations are based upon information obtained on the sport fishery for both immature and mature fish, as well as information obtained by biological study of individual stream systems.

Information on the mature steelhead trout was obtained from scale readings of adults caught in the sport fishery of several of our rivers. To supplement the work done by Pautzke and Meigs (1940) and by Meigs and Pautzke (1941) on the Green River, scale studies were conducted on the Cowlitz River in 1946-47 and 1947-48, on the Chehalis River in 1947-48, and on the Hoh River in 1948-49 and 1949-50.

The Green, Cowlitz, and Chehalis Rivers are typical lowland streams of western Washington. All arise in mountainous country and flow through considerable lowland farming and industrial areas. The Hoh River is a glacial-fed stream that flows through forest from its source to its mouth. There are no industrial developments on the river and only a few small farms.

The scale readings (Tables 4-8) revealed that the sports-caught steelhead trout of the different river systems were a fairly homogenous population. The age composition of the sport-caught steelhead trout consisted predominantly of 4-year-old fish with 5-year-old fish making up the second largest group (Table 4). The sport catch was made up primarily of first-time spawners; the percentage of re-spawners varied from 4.4 in 1946-47 in the Cowlitz River to 14.0 in the 1948-49 Hoh River catch (Table 5). The percentage of re-spawners entering the catch evidently depends upon escapement to the spawning grounds the year before, and this seems to be dependent upon water conditions. The large percentage of re-spawners entering the catch in the Hoh River in 1948-49 was undoubtedly the result of the long periods of high water during the

TABLE 4.—Percentage age composition, of steelhead trout caught in the sport fishery of the Green, Chehalis, Hoh, and Cowlitz Rivers as determined from scale readings

Age (number of annuli)	River and year						
	Green 1940	Green 1941	Chehalis 1948	Hoh 1949	Hoh 1950	Cowlitz 1947	Cowlitz 1948
2.....	0.0	1.0	0.0	0.0	0.0	0.0	0.0
3.....	13.0	19.7	12.0	2.3	2.7	5.0	6.0
4.....	60.0	60.1	63.0	73.3	68.4	71.0	61.0
5.....	23.0	16.7	22.0	19.8	26.2	23.0	32.0
6.....	4.0	2.5	3.0	4.6	2.7	1.0	1.0

TABLE 5.—Percentage of re-spawners caught in the steelhead trout sport fishery of the Green, Chehalis, Hoh, and Cowlitz Rivers

River	Year	Re-spawners	River	Year	Re-spawners
Green.....	1940	5.0	Hoh.....	1950	6.7
Green.....	1941	6.9	Cowlitz.....	1947	4.4
Chehalis.....	1948	9.0	Cowlitz.....	1948	7.8
Hoh.....	1949	14.0			

1947-48 season, when flood conditions caused the sport catch and the Indian catch to drop to a low level. The percentage of re-spawners in the 1949-50 season dropped to 6.7 percent undoubtedly due to good fishing conditions during the 1948-49 season for both the sport fishermen and the Indians.

Most steelhead trout were 4 years old at sexual maturity, with the second largest group consisting of 5-year-old fish (Table 6). The majority of the 4-year-old steelhead had spent 2 years in fresh water and 2 years in salt water before returning to spawn (Table 7).

Most of the steelhead trout spent 2 years in fresh water before reaching migratory size and the next largest group spent only 1 year in fresh water (Table 8). The Green, Chehalis, and Cowlitz Rivers were similar in percentages of steelhead reaching migratory size in 1 year but the Hoh River differed considerably.

The largest group of steelhead trout spent 2 years in salt water before returning to spawn; those that spent 3 years in salt water contributing to the second largest group (Table 9).

TABLE 6.—*Age at maturity of steelhead trout caught in the sport fishery of the Green, Chehalis, Hoh, and Cowlitz Rivers*

[The figures shown represent the percentage of the total sample]

River	Year	Age (number of annuli)				
		2	3	4	5	6
Green.....	1940	2.0	14.0	61.0	21.0	2.0
Green.....	1941	2.5	22.2	61.5	11.8	2.0
Chehalis.....	1948	0.0	11.0	71.0	17.5	0.5
Hoh.....	1949	0.0	3.5	81.4	15.1	0.0
Hoh.....	1950	0.0	3.3	73.0	21.0	0.7
Cowlitz.....	1947	0.0	5.2	74.3	20.1	0.4
Cowlitz.....	1948	0.0	5.9	61.1	32.6	0.4

TABLE 7.—*Freshwater and saltwater winter checks on scales of steelhead trout caught in the sport fishery of the Green, Chehalis, Hoh, and Cowlitz Rivers*

[Percentage of total sample in each group]

Freshwater and saltwater winter checks	River and year						
	Green 1940	Green 1941	Chehalis 1948	Hoh 1949	Hoh 1950	Cowlitz 1947	Cowlitz 1948
1-1.....	0.0	1.5	0.0	0.0	0.0	0.0	0.0
1-2.....	10.0	12.8	4.0	0.0	2.0	2.0	4.0
1-3.....	6.0	5.9	5.0	3.5	0.7	10.0	8.0
1-4.....	0.0	0.0	0.5	0.0	0.0	1.0	1.0
2-0.....	2.0	1.0	0.0	0.0	0.0	0.0	0.0
2-1.....	4.0	9.4	7.0	3.5	1.3	3.0	2.0
2-2.....	52.0	51.2	66.0	77.9	71.1	63.0	52.0
2-3.....	17.0	8.4	15.0	10.5	17.5	19.0	26.0
2-4.....	0.0	1.5	0.5	0.0	0.0	0.0	0.0
3-1.....	3.0	4.4	0.0	0.0	0.0	0.0	1.0
3-2.....	4.0	3.4	2.0	4.6	6.7	1.0	5.5
3-3.....	2.0	0.5	0.0	0.0	0.7	1.0	0.5

TABLE 8.—*Freshwater winter checks on scales of adult steelhead trout caught in the sport fishery of the Green, Chehalis, Hoh, and Cowlitz Rivers*
[Percentage of the total samples for each stream]

Freshwater winter checks	River and year						
	Green 1940	Green 1941	Chehalis 1948	Hoh 1949	Hoh 1950	Cowlitz 1947	Cowlitz 1948
1.....	16.0	20.2	10.0	3.5	2.7	13.0	13.0
2.....	73.0	71.4	88.0	91.9	89.9	85.0	80.0
3.....	10.0	8.4	2.0	4.6	7.4	2.0	7.0
4.....	1.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 9.—*Saltwater winter checks on scales of adult steelhead trout caught in the sport fishery of the Green, Chehalis, Hoh, and Cowlitz Rivers*
[Percentage of the total samples for each stream]

Saltwater winter checks	River and year						
	Green 1940	Green 1941	Chehalis 1948	Hoh 1949	Hoh 1950	Cowlitz 1947	Cowlitz 1948
0.....	1.0	0.0	0.0	0.0	0.0	0.0	0.0
1.....	8.0	12.8	7.0	2.3	0.7	3.0	4.0
2.....	61.0	65.0	65.0	75.6	76.5	64.0	61.0
3.....	28.0	20.2	24.0	16.3	20.8	32.0	34.0
4.....	2.0	2.0	3.0	5.8	2.0	1.0	1.0
5.....	0.0	0.0	1.0	0.0	0.0	0.0	0.0

The weight of steelhead trout in the various age groups differed considerably. Those within any age group that spent the longest time in salt water attained the largest size. On the Chehalis River in 1947-48, the weight of 3-year-old steelhead trout varied from 2.5 to 7.25 pounds; the 4-year-olds ranged from 4.75 to 11.25 pounds; the 5-year-olds from 5.5 to 18 pounds; and the 6-year-olds from 5.5 to 20 pounds. The 5.5-pound fish in the 6-year-old group was fully spent. All of the largest steelhead trout in each age group had spent more time in salt water than had smaller fish. The average weight for all steelhead checked in the sport fishery was 7.8 pounds. The figures on the Chehalis River steelhead trout are given only to point out the great variation in size of fish of the same age. The extreme limits of weight and average weight of steelhead vary among the river systems.

An interesting aspect of the behavior of young steelhead trout (not related to our management policies) is the migration of fry that takes place shortly after the yolk sac has been absorbed. Sumner (1953) noted this fry migration in Jewell Creek, tributary to Sand Creek during May and June. The migration reached its peak in the second week of June and then rapidly dropped off. A similar occurrence has been noted in the Wynooche River, tributary to the Chehalis River.

The city of Aberdeen has an industrial water intake located approximately 7 miles upstream from the mouth of the river. This intake is

located at right angles to the river and draws some 34 million gallons of water per day. All fish entering the basin, located in front of the entrance to the pipe line, are trapped in a raisable metal trap, counted, and released into the main river below the intake. Accurate records of the number of fish entering this trap have been maintained for the past 3 years.

The fry first appear in the trap sometime during May and reach a peak from the latter part of June to the middle of July. The drop in abundance is very rapid after the peak is reached. In 1952, the first fry entered the trap on May 31 and the last on August 15. The peak of abundance came during the last week of June. In 1953, the first fry entered the trap on May 12 and the last on August 5. The peak came during the second week of July although a lesser peak occurred during the second week of June. In 1954, the first fry entered the trap on May 20 and the last on August 5. The peak of abundance came during the last week of June with a lesser peak in the second week of July. The number of fry entering the trap in 1952 was 415, while in 1953 the number increased to 2,058, and in 1954 the number was 2,200.

The destination of these fry is unknown. Scale readings of mature steelhead trout have shown no evidence of migration into salt water as fry. It is felt that these fry are merely distributing themselves more suitably throughout the river system. Spawning areas are at times so heavily utilized in some parts of the river that heavy concentrations of fry in any one area would result in extreme competition for the available food and "Lebensraum". Consequently the fry drift downstream searching for areas of less competition.

The results of reading scales from adult steelhead trout gave us life history information as well as information on the regulating length of the steelhead season. The fishing regulations in the state had become ultra-conservative as the number of steelhead fishermen increased each year. The length of the steelhead trout season was shortened mainly to allow the spawned-out fish to return to the sea at the cost of allowing fresh runs of fish to move upstream unmolested. The late runs of steelhead were being wasted. The scale readings showed that only a small percentage of the re-spawning steelhead trout was contributing to the sport catch each year. Furthermore, work done by Pautzke and Meigs (1940) and by Meigs and Pautzke (1941) on the Green River steelhead trout revealed that adult fish suffered a 58-percent loss after spawning and Sumner (1953) found a 48-percent loss in Sand Creek. The primary consideration then should be to protect the spawning population but not to worry excessively about the fishing pressure on the spawned-out fish. (Actually, few fishermen keep these spent steelhead.) The assignment of a "deadline" or point on each stream above which fishing is prohibited protects the early spawners, which move on upriver. During any extended season, that is, seasons after the end of February, the deadline is moved downstream to protect the adults that are spawning in the lower reaches. It has been found that if the deadline on a stream is shifted as the season progresses,

fresh-run steelhead trout are in the fishing zone rather than spawners.

Concern that predominantly females are taken in a late fishing season and that the spawning potential of a stream is thereby reduced, does not seem to be justified. The escapement of steelhead trout appears to be adequate during any of the fishing months to insure that enough adults reach the spawning grounds. On the Samish River, for example, the catch was determined to be only 40 percent of the total run during the fishing season. The Samish River is a very small stream and is accessible for nearly its entire length. In larger rivers that are less accessible than the Samish, the catch would necessarily be considerably less than 40 percent of the total run. The Satsop River, comparatively a large stream, had greater escapement through the trap, located on one of the smaller tributaries, than were caught in the sport fishery in 1952-53.

Further information on exploitation rate is available from Bingham Creek where the escapement through the trap during the fishing season was 38 percent of the total Bingham Creek run. The season ran from the first Sunday in December until the last of February. Bingham Creek is only one of the smaller tributaries of the Satsop River. Two tributaries are larger, one is of the same size, and one is smaller. In 1953-54, when the season extended until April 30 the escapement ran 37 percent of the total run. It is evident that the escapement of adult steelhead trout is considerably higher in the Satsop River than the above quoted figures. The escapement percentages for both 1952-53 and 1953-54 were nearly the same even though the season in 1953-54 was 2 months longer than in 1952-53. Some steelhead trout coming through the trap after the fishing season closed should be considered to be in the fishing zone during the open season, but it is not known how long it takes the adult fish to move into the trap after entering the river. The addition of these steelhead would raise the percentage escapement.

One major change made in the regulations of the sport fishery for immature steelhead trout was the substitution of a July 1 opening in the lower reaches of our steelhead streams for the usual opening on the third Sunday in May. Although the peak of migration of young steelhead trout normally is during the first 2 weeks in May in many of our streams during most years, this pattern does not hold universally. Many of our steelhead streams have migrants in large numbers concentrated in the lower reaches of the river during June. The time of the migration varies from year to year seemingly depending upon water conditions. Sampling of the lower areas of streams of the Olympic Peninsula has shown large numbers of migrant steelhead trout moving out of the stream as late as the first part of July. This late migration appears to be in addition to an earlier migration in May. The late migration also appears to be mainly in summer-run steelhead trout streams, although it does occur in streams without summer runs. Whether the coldness of the water in these rivers or the time of spawning causes the late migration, or whether these migrants in summer-run steelhead streams are "summer-run migrants" is unknown. The July 1 opening gives complete protection to migrant steelhead trout in the great majority of our streams and gives uniformity

to the seasons. The value of the July 1 opening has not been ascertained as yet, but it is hoped that the more effective protection of downstream migrants will assist in bolstering the runs of adult steelhead trout.

A problem still facing the Department of Game is the extensive fishery in some of our streams for immature steelhead trout during the fall. Large numbers of the following year's migrants which reach the 6-inch size limit in late August and September are heavily fished by tourists and local fishermen camped on our streams. It is not felt that the general fishing public is ready for a closure of the streams at this time or for a larger minimum size limit on all of our streams. The 10-inch minimum size in effect on some of the steelhead streams at the present time appears to be working very well, but, the invoking of a 10-inch minimum size limit on all steelhead trout streams will require proper education of the summer trout fishermen. Because many of the rehabilitated lakes are closed by September, many fishermen move to the streams after this time. It is true that late August and September are the best fishing months for sea-run cutthroat trout, but not all of our streams have this species and cutthroat trout are more difficult to catch than the young steelhead trout. Although our streams contain legal-sized steelhead trout the year around, the numbers of the 6-inch fish are not particularly abundant until the fall months.

Another problem that confronted the fishery management division was the development of methods of regulating the total catch per individual fisherman and of determining the total catch of steelhead trout taken from each stream. It was essential that the catch of each stream be known, if stream-management policies are to be evaluated. To solve the problem of estimating the total catch as well as limiting the catch per individual per season, a punched card system was devised. Every fisherman is required to have a "steelhead punched card" in his possession while fishing during the steelhead trout season. When a steelhead is caught, the fisherman is required to remove immediately a punch from his card and record the date of catch and the stream on which the fish was caught. Each card has 24 such spaces. On the back of the card is a space for listing the streams that are fished without success. At the end of the steelhead trout season, which normally runs from the first Sunday in December until the end of April, the fisherman is required to turn in his punched card to his license dealer or to the Department of Game. The catch records on these cards are then tabulated and an estimated total catch for each stream is computed (Table 10). The normal return of these cards is from 25 to 35 percent.

The Department realizes the possibility of error in determining the total catch of each stream by the use of the returned cards only, but the figures obtained can readily be used as an indication of the success or failure of a stream from season to season. Many other interesting facts are told on the cards as well, which assist in obtaining a better understanding of the fishery for adult steelhead trout.

For example, the data taken from the punched cards returned in 1953 revealed that 47.4 percent of those fishermen who returned their cards had

TABLE 10.—The total number of "steelhead punched cards" used and the estimated total catch for each winter steelhead trout season since 1948-49

Winter season	Total punched cards used	Estimated total catch	Winter season	Total punched cards used	Estimated total catch
1948-49.....	40,000	40,899	1951-52.....	62,500	118,285
1949-50.....	51,000	56,662	1952-53.....	77,300	123,231
1950-51.....	50,000	61,769	1953-54.....	89,342	162,500

fished with success. The percentage of total catch per month showed that 27.7 percent was made during December, 21.0 percent in January, 31.7 percent during February, 18.2 percent in March, and 1.4 percent during April.

Of the fishermen reporting, 12.8 percent caught at least one daily limit of three steelhead trout, 32.7 percent caught two steelhead on at least one occasion, and 54.5 percent did not catch more than one steelhead in any one day of fishing.

The total number of steelhead trout reported showed that 11.7 percent of the catch was represented by limits of three fish, 23.8 percent by catches of two fish in one day, and 64.5 percent by not more than one fish in any one day.

Of the fishermen who caught limits of steelhead trout during the season, 72.3 percent caught only one limit, 18.8 percent took two limits, 6.0 percent had three limits, 1.7 percent caught four limits, and 1.1 percent took five limits, and 0.1 percent caught six limits.

The number of punched cards used by steelhead fishermen has increased each year as has the catch of steelhead trout. When the number of fishermen will stop increasing and the catch of steelhead trout will level off only time will tell.

The use of the punched cards for estimating the catch of steelhead trout in any one stream is far more successful than trying to estimate the total catch by a creel census. Coverage by creel census is necessarily limited; information could be had only for streams that could be adequately checked each year.

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ECOLOGY OF THE CUTTHROAT TROUT IN HENRYS LAKE, IDAHO¹

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ABSTRACT

Henrys Lake, a 6,500-acre reservoir at the elevation of 6,472 feet in eastern Idaho, has a maximum depth of 21 feet and an average depth of 12 feet. Seasonal variation of weather and shallow, fertile waters are the major environmental factors that influence the Henrys Lake biotic community. Phytoplankton is abundant and composed primarily of blue-green algae and cladocerans and copepods are the dominant zooplankters. Higher aquatic vegetation has developed over the entire bottom of the lake. The standing crop of bottom and plant-inhabiting fauna in Henrys Lake for 1951 is estimated to have been 606 pounds per acre.

Fish species found in Henrys Lake are: Cutthroat trout, *Salmo clarki*; Rocky Mountain sculpin, *Cottus bairdi semiscaber*; and mountain whitefish, *Prosopium williamsoni* as native species. Introduced fish are: rainbow trout, *Salmo gairdneri*; eastern brook trout, *Salvelinus fontinalis*; and reidside shiner, *Richardsonius balteatus hydrophlox*. Rainbow trout and rainbow $\times$ cutthroat hybrids were rare in the sport catch. Cutthroat trout and brook trout entered the creel in the ratio of 4 to 1.

The body-scale relationship is described by a second-degree parabola. Cutthroat trout attain an average standard length of 21.6 millimeters prior to scale development. Analysis of scales provides evidence that the growing season of the cutthroat trout is limited to the open-water period of approximately 180 days, mid-May to mid-November.

Male cutthroat trout of the 1951 sport catch matured at ages II and III while females matured at ages III and IV. Of 500 mature cutthroat trout marked and released from the Henrys Lake Spawning Station in the spring of 1950, only 12 were taken in the sport-catch. This low recovery indicates these marked trout suffered a severe natural mortality subsequent to spawning.

The considerable variation of growth in length among the Henrys Lake cutthroat trout is attributed to individual differences in the time spent in tributary streams as compared to time spent in lake, seasonal variation of environmental conditions, and different age at maturity between male and female fish. The rate of growth in weight continues to increase during the trout's second and third years whereas the rate of growth in length declines after the first year.

The sex ratio of female to male cutthroat trout in the 1951 sport catch declined not only with increase in age but also as the fishing season progressed.

The midge-shrimp-damselfly food group comprised 90 percent by number and 74 percent by volume of the food utilized by the Henrys Lake cutthroat trout during the study period. The pronounced decline in feeding activity that occurred during August may have been due to the relatively high temperature and relatively low oxygen tension of the lake waters during this period.

Pathogenic bacteria infected mature cutthroat trout of the 1950, 1951, and 1952 spawning migrations. The death of an estimated 3,600 cutthroat trout of all age-groups in small, open-water areas at the mouths of 3 tributary streams

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during January 1952, has been attributed to asphyxiation due to local oxygen depletion.

The curves of growth in length and growth in weight of the Henrys Lake cutthroat trout are descriptive of a short-lived population. The mortality of the Henrys Lake cutthroat trout due to disease, asphyxiation, predation, and capture by anglers plus mortality of mature cutthroat trout subsequent to spawning (due possibly to causes both environmental and genetic in nature) combine to give a low average age and limit the number in the population.

INTRODUCTION

During the spring of 1950, approximately 10 thousand cutthroat trout that averaged 3 pounds in weight entered the trap at the Henrys Lake Spawning Station. Spawning migrations composed of numerous and large cutthroat trout are uncommon. This ecological study was initiated to determine some of the factors responsible for this unusual population of cutthroat trout and to provide management information.

Henrys Lake, located in eastern Idaho at the elevation of 6,472 feet above mean sea level, is a reservoir with a storage capacity of 79,351 acre-feet and has a surface area of approximately 6,500 acres (Anonymous, 1950). The lake is roughly rectangular, 4 miles by 3 miles; the major axis lies north and south. The east and west shorelines slope gradually, with depths of 10 feet common as far as a quarter-mile from shore. In contrast, north and south shores are abrupt; 15-foot depths are attained within 100 feet from shore. The lake bottom is relatively flat. The maximum depth is 21 feet in the central portion and the average depth is 12 feet.

Prior to the construction of a 15-foot dam across its outlet in 1922, Henrys Lake was approaching extinction. In 1912, after careful sounding, Kemmerer, Bovard, and Borman (1924) found the lake to have a maximum depth of 6.5 feet and an average depth of 4.8 feet. In spite of the shallow depth, the lake contained a large population of cutthroat trout. During the latter part of the past century, mining communities near Virginia City, Montana, were supplied with trout caught from Henrys Lake.²

The Henrys Lake watershed of 104 square miles drains a range of mountains that is a part of the Continental Divide and borders the lake on three sides. These mountains, composed of quartzites, limestones, dolomites, and shales, profoundly influence the climate of the Henrys Lake area and provide the basic mineral supply of the lake waters.

LIMNOLOGY OF HENRYS LAKE

Physical-chemical conditions.—In addition to the primary limitations of mineral supply, the productivity of Henrys Lake is affected by the climate and by its shallow depth. Ice and deep snow cover the lake from about mid-November to mid-May, and this cover is complete except for very

² Mrs. Mary Ann Sherwood, owner of Sherwood's Museum, Henrys Lake, Idaho, in conversation with the author.

small areas at the mouths of three tributaries. Since photosynthesis is not possible in the absence of light and even though the lake waters are near freezing, the processes of decomposition and respiration reduced the oxygen tension from 8.1 p.p.m. in the ice-free water during September 1951 to 5.9 p.p.m. in the water under the ice during April 1952. These processes, during the same period, increased the concentration of ammonia, as nitrogen, from 0.3 p.p.m. to 0.5 p.p.m. and increased the carbon dioxide tension from less than 1 p.p.m. to 16.5 p.p.m. The increase in carbon dioxide caused a drop in the pH from 8.4 to 7.2. Carbon dioxide, as bound carbonate, was absent, but as bicarbonate averaged 130 p.p.m. during the ice-free period.

Nights are cool and days warm in the summer. The prevailing wind is relatively gentle and from the southeast, but several mountain passes over the Continental Divide provide avenues for frequent brisk winds that aerate the lake waters. These winds quickly warm the shallow lake waters in the spring and, as quickly, cool them in the fall. The surface-water temperatures in 1951 ranged from 48° F. in early June to 68° F. in mid-August and dropped to 51° F. by late September. The bottom temperatures ranged from 1° to 7° F. less than the surface temperatures, depending upon the intensity and length of the windstorms. As a result of the wind action and the shallow depth of the lake, thermal stratification did not develop during 1951. From these observations, Henrys Lake may be classified as a temperate lake of the third order (Welch, 1935).

Plankton.—Horizontal plankton samples were collected with a 200-mesh Wisconsin plankton net and analyzed quantitatively according to methods described by Reighard (Ward and Whipple, 1918). Horizontal hauls of plankton yielded 11.1 and 196 cubic centimeters per cubic meter for June and September, respectively.

The dominant phytoplankton forms during 1951 were *Aphanizomenon flos-aquae*, *Gloeotrichia* sp. and *Anabaena flos-aquae*, all blue-green algae. *Gloeotrichia* sp. reached maximum abundance in July and *Aphanizomenon flos-aquae* reached a maximum and was extremely abundant in the form of floating mats during September.

Prescott (1939) and Kemmerer, Bovard, and Borman (1924) pointed out that the nitrogen demand by blue-green algae is so strong that their presence may be used as an index of high nitrogen concentration and organic wastes. Solutions of organic-waste deposits from heavily grazed meadowland adjacent to Henrys Lake are very likely carried into the lake by the spring run-off and later in the season during periods of heavy irrigation.

The zooplankters, *Daphnia* spp., *Diaptomus leptopus*, and *Cyclops vavus*, were common in both horizontal and vertical plankton hauls, but their numbers were obscured by the tremendous amount of phytoplankton.

Higher aquatic vegetation.—Higher aquatic vegetation has become abundant over the entire bottom of the lake except the inshore zone which is relatively barren due to the intensive wave action. The important species are: three pondweeds, *Potamogeton richardsonii*, *Potamogeton zosteriformis* and *Potamogeton pectinatus*; waterweed, *Anacharis canadensis*; and

smartweed, *Polygonum amphibium*. Willows are located along drowned stream channels and, although dead, are important as a habitat for aquatic invertebrates. The pondweeds, especially *Potamogeton richardsonii*, grow rapidly and extend their flowering heads above the lake surface by early July.

Bottom fauna.—Three samples were collected with a 6- by 6-inch Ekman dredge at each of three representative stations once each month from June through September, 1951. Samples were strained through a 14-mesh screen and organisms were sorted by species and life stage. Volumes were measured to nearest 0.1 cubic centimeter by water displacement.

The 36 samples had an average count of 175 organisms with an average volume of 6.1 cubic centimeters per square foot of lake bottom (Table 1).

TABLE 1.—*Bottom fauna and plant-inhabiting fauna from Ekman-dredge and tow-net samples from Henrys Lake, Idaho, during summer of 1951*

[Expressed as percentage frequency of occurrence in samples, percentages of numbers, and percentages of volumes]

Organism	Bottom fauna			Plant-inhabiting fauna		
	Occurrence	Number	Volume	Occurrence	Number	Volume
Insects.....	100	58	10	88	31	19
Midge larvae.....	100	54	8	88	9	2
Midge pupae.....	42	2	1	63	4	1
Mayfly nymphs.....	..	..	..	25	Tr.	Tr.
Water boatman, adults.....	..	..	..	38	1	Tr.
Caddisfly larvae.....	33	1	Tr. ¹	63	1	2
Damselfly nymphs.....	17	1	1	88	16	14
Amphipods.....	92	17	9	88	54	46
Water mites.....	75	4	Tr.	88	4	Tr.
Leeches.....	92	10	33	63	1	3
Oligochaete worms.....	83	7	1	..	..	..
Snails.....	42	2	11	88	10	30
Mussels.....	33	2	36	..	..	..
Sculpins.....	..	..	..	13	Tr.	2

¹ Trace; numbers or volume percentage less than 0.5 percent

The standing crop of bottom fauna in Henrys Lake in 1951 is estimated to have been 586 pounds per acre. The bottom populations of Henrys Lake are comparable to those of Heenan Lake, California, (Calhoun, 1944a) and of Fish Lake, Utah (Hazzard, 1935).

Plant-inhabiting fauna.—The animal forms inhabiting the dense aquatic vegetation were not sampled by either the bottom dredge or the plankton net. In order to sample these forms, a 14-mesh, bronze screen tow-net was constructed in the shape of a truncated cone with base (mouth) diameter of 1 foot and a length of approximately 3 feet. Plant-inhabiting fauna were collected by pulling the tow-net through the water 100 seconds at the rate of 1 yard per second. During the haul, the tow-net traversed a course that began near the surface, descended gradually to near the bottom and toward the end of the haul rose again to the surface. The relatively coarse mesh of

the townet strained the fauna from an estimated 8.6 cubic yards of water during the above-described haul.

Numerous rooted aquatics were pulled loose from the bottom by the sampler as it was towed through the water. Plant parts protruding outside the sampler at the end of the haul were broken off and discarded. Animals from included plant parts were removed and counted as the plant-inhabiting part of the sample.

Eight townet samples were measured and sorted in a manner similar to that for the dredge samples. The samples indicated an average density of plant-inhabiting fauna in Henrys Lake to be 19 organisms per cubic yard with an average volume of 0.46 cubic centimeters (Table 1). The standing crop of plant-inhabiting forms in Henrys Lake for 1951 is estimated to have been 20 pounds per acre.

FISHES OF HENRYS LAKE

The original range of the cutthroat trout in the United States is the Rio Grande, Columbia, Missouri, Colorado, and Great Basin drainages and some coastal streams of the Pacific Ocean (Mottley, 1934; Miller, 1950). The upper Snake River drainage, of which Henrys Lake is a part, was formerly part of both the Columbia and Great Basin drainages.

A small portion, if any, of the existing cutthroat trout population in Henrys Lake is descended from the original stock since cutthroat from both Yellowstone Lake, Wyoming, and Gold Creek, Idaho, have been introduced. In addition, the rainbow trout has been stocked in Henrys Lake and hybrids of the rainbow $\times$ cutthroat trout are present.

Fish species native to Henrys Lake include the cutthroat trout, rocky mountain sculpin, and mountain whitefish. Introduced species include the rainbow trout, eastern brook trout, and redbreasted shiner. The latter was probably introduced via the anglers' minnow buckets.

Cutthroat trout and brook trout entered the creel in a ratio of 4 to 1, during the 1951 creel census period. The rainbow trout, rainbow $\times$ cutthroat trout hybrids and the mountain whitefish are probably present in limited numbers as they are rarely caught by the angler.

BODY-SCALE RELATIONSHIP OF CUTTHROAT TROUT

By use of a measuring board graduated in millimeters, total, fork, and standard body-length measurements were taken from 378 cutthroat trout in 1950 and 1951 according to methods described by Lagler (1950), as follows: total length—from tip of snout to end of tail with caudal rays squeezed together; fork length—from tip of snout to notch in tail; and, standard length—tip of snout to base of caudal fin rays where a groove forms naturally when the tail is bent from side to side. Length conversion factors for the Henrys Lake cutthroat trout were calculated, as follows: total length equals 1.153 times standard length and also equals 1.031 times fork length.

Scale samples as well as body-length measurements were collected from the above-described cutthroat trout. Scales were sampled from the left side of each trout midway between the lateral line and origin of the dorsal fin. An average of 8 scales from each trout were cleaned and mounted on a slide in a medium of gum arabic. The mounted scales were inspected and, on the basis of uniformity and shape, a representative scale was chosen and marked for use in the analyses of age composition, growth in length and body-scale relationship.

The relationship between the standard body length and the anterior scale radius ($\times 37$) of cutthroat trout was determined to serve as a basis for calculation of growth in length. The data from 366 fish were grouped into 25-millimeter intervals of standard length, and the mean body length, mean scale measurement and the body-scale ratio (L/Sc) were determined for each group (Table 2).

TABLE 2.—Body-scale relationship (L/Sc) of 366 Henrys Lake cutthroat trout arranged by 25-millimeter intervals of standard length with age groups combined

Mean standard length	Mean scale measurement ($\times 37$)	L/Sc ratio	Number of fish	Mean standard length	Mean scale measurement ($\times 37$)	L/Sc ratio	Number of fish
43	4	10.7	10	312	34	9.2	20
58	7	8.3	11	340	37	9.2	21
87	10	8.7	14	364	40	9.1	31
109	12	9.1	10	389	43	9.0	43
137	15	9.1	8	411	45	9.1	59
166	15	11.1	3	439	48	9.1	44
187	19	9.8	2	462	50	9.2	32
218	25	8.7	2	485	53	9.2	11
243	26	9.4	10	509	55	9.2	8
264	29	9.1	14				
289	34	8.5	13				
				Weighted average.....		9.1	

The relation of standard length in millimeters to the anterior scale radius in millimeters ($\times 37$) of the Henrys Lake cutthroat trout was described satisfactorily by the following parabola (Fig. 1):

$$L = 21.59 + 6.879 R + 0.03874 R^2$$

From this body-scale relationship, it is evident that cutthroat trout scales grow relatively faster than the body, but at a progressively slower rate for the remainder of the trout's life. Van Oosten (1929) found a similar body-scale relationship in the lake herring, *Leucichthys artedii* Le Sueur.

Current-season growth on scales from 16 ripe cutthroat trout trapped in Hatchery Creek during May 1951 ranged from 'no growth' to 2 circuli beyond the current annulus. On scales of 6 cutthroat trout caught in the mouth of Hatchery Creek on November 23, 1951 when the lake was ice-covered, the last 2 or 3 circuli were incompletely formed. Though this sample is small, it is postulated that scale growth ceases at the time of ice-

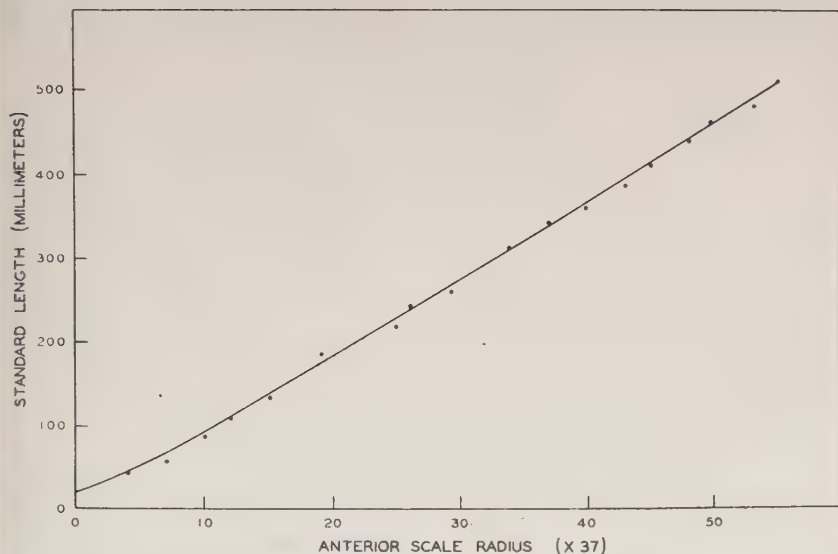


FIGURE 1.—Body-scale relationship of 366 cutthroat trout from Henrys Lake. The dots are based on the means of Table 2.

cover formation and is renewed and the annulus formed when the ice-cover melts in May. These scale samples also provide evidence that the trout growing season in Henrys Lake is limited to the open-water period of approximately 180 days, mid-May to mid-November.

AGE COMPOSITION

Age composition of the cutthroat trout population of Henrys Lake was not determined. Collection of samples by seines proved impossible due to the dense growth of aquatic vegetation, and possible high mortality prohibited the use of gill nets. However, the age composition and maturity of cutthroat trout taken in the sport-catch of June-July, 1951 were determined (Table 3).

Through the age composition and maturity of cutthroat trout in this sport-catch were surely not representative of the cutthroat population in the lake, it may be safely concluded that some of the Henrys Lake male cutthroat trout mature at age II, while some of the Henrys Lake female cutthroat trout do not mature until age IV.

Cutthroat trout of age-group 0 and smaller cutthroat of age-group I were likely excluded from the sport-catch due to the large lures used by the Henrys Lake angler.

Cutthroat trout of age-groups II, III, and IV comprised 80 percent of the sample collected from the June-July 1951 sport-catch. By stage of ma-

TABLE 3.—Age (number of annuli) and maturity¹ of 226 cutthroat trout sampled at random from the Henrys Lake sport-catch during June and July, 1951

[Expressed as percentage of sample]

Age group	Male		Female		Total
	Immature	Mature	Immature	Mature	
I.....	6	..	6	..	12
II.....	2	10	16	..	28
III.....	..	9	21	3	33
IV.....	..	14	..	5	19
V.....	..	4	..	3	7
VI.....	..	..	..	1	1
Total.....	8	37	43	12	100

¹ Mature trout are defined as those which had spawned or would have spawned during the spring of 1951.

turity, immature females and mature males of age-groups II, III, and IV comprised 70 percent of this sample.

The small percentage of cutthroat trout from age-groups V and VI in the sport-catch is believed due to an actual scarcity of fish of these age-groups in the lake. During May 1950, 500 mature cutthroat trout from the Henrys Lake Spawning Station were marked with locking strap tags around the lower jaw and returned to the lake subsequent to spawning. Only twenty or 4 percent of the marked trout were recovered.

Of the marked trout recovered, 9, 2, and 1 were taken in the sport-catches of 1950, 1951, and 1952, respectively, while 7 and 1 were re-trapped at the Henrys Lake Spawning Station during 1951 and 1952, respectively. The return of only 2.4 percent of the mature marked trout to the creel indicates that these cutthroat trout suffered a severe mortality subsequent to spawning.

Analysis of scale samples from the larger cutthroat trout taken in the 1951 sport-catch and trapped in the Henrys Lake Spawning Station during the 1950 and 1951 spawning migrations indicates the maximum age of the Henrys Lake cutthroat is 6 years. However, since only 8 percent of the June-July 1951 sport-catch was composed of cutthroat of age-groups V and VI, the longevity of the Henrys Lake cutthroat from the angler's viewpoint was but 4 years.

GROWTH IN LENGTH

Calculations of growth in length were made with a nomographic device of the type described by Carlander and Smith (1944). Standard lengths and annual increments of lengths were calculated from measurements of scales collected from Henrys Lake cutthroat trout during 1950 (Table 4) and 1951 (Table 5). The relationship between age and length of cutthroat trout sampled in 1951 is described by Fig. 2.

Considerable variation of growth in length occurred within age groups from the same and different samples of Henrys Lake cutthroat collected in

TABLE 4.—*Calculated standard lengths and annual increments of lengths (millimeters) for the Henrys Lake cutthroat trout collected in 1950*

Age group	Number of fish	Standard length at capture	Calculated length at end of year of life			
			1	2	3	4
I.....	1	221	170	...	...	...
II.....	19	318	124	274	...	...
III.....	18	390	131	263	364	...
IV.....	10	422	117	267	378	421
Grand average.....			126	269	369	421
Increment.....			126	143	104	43
Equivalent total length (inches).....			5.7	12.2	16.7	19.1
Increment.....			5.7	6.5	4.7	2.0
Number of fish.....			48	47	28	10

TABLE 5.—*Calculated standard lengths and annual increments of lengths (millimeters) for the Henrys Lake cutthroat trout collected in 1951*

Age group	Number of fish	Standard length at capture	Calculated length at end of year of life					
			1	2	3	4	5	6
0.....	9	144	...	...	...	...	...	...
I.....	36	274	197	...	...	...	...	...
II.....	76	348	163	302	...	...	...	...
III.....	96	400	136	277	374	...	...	...
IV.....	76	440	133	278	384	435	...	...
V.....	23	480	139	278	388	443	478	...
VI.....	1	515	80	240	400	470	500	515
Grand average.....			149	284	380	437	479	515
Increment.....			149	142	102	52	34	15
Equivalent total length (inches).....			6.8	12.9	17.3	19.9	21.7	23.4
Increment.....			6.8	6.5	4.7	2.4	1.5	0.7
Number of fish.....			308	272	196	100	24	1

1951 (Table 6). Difference in length at capture of cutthroat trout of the 0 groups collected during August from tributary streams as compared to those of age-group 0 collected from the lake indicate greater length was attained by the cutthroat which migrated to the lake. The large amount of variation of growth in length within age-groups is attributed to the relative time spent in stream or lake environment during the first year of life subsequent to hatching.

Further evidence of variation of growth in the first year of life of the Henrys Lake cutthroat trout within and between age-groups was noted in the variation in the number of circuli between the focus and the first annulus on scales from cutthroat trout of age-groups, as follows: I—14 to 26 circuli; II—12 to 29 circuli; III—12 to 20 circuli; IV—10 to 20 circuli; and V—13 to 21 circuli. These circuli counts of Henrys Lake cutthroat exceed the 7 to 9 circuli found within the first annulus on scales from Logan River, Utah, cutthroat (Fleener, 1952) and the 6 to 11 circuli within the first annulus on scales of cutthroat trout from two mountain lakes in Wyoming (Robertson, 1947).

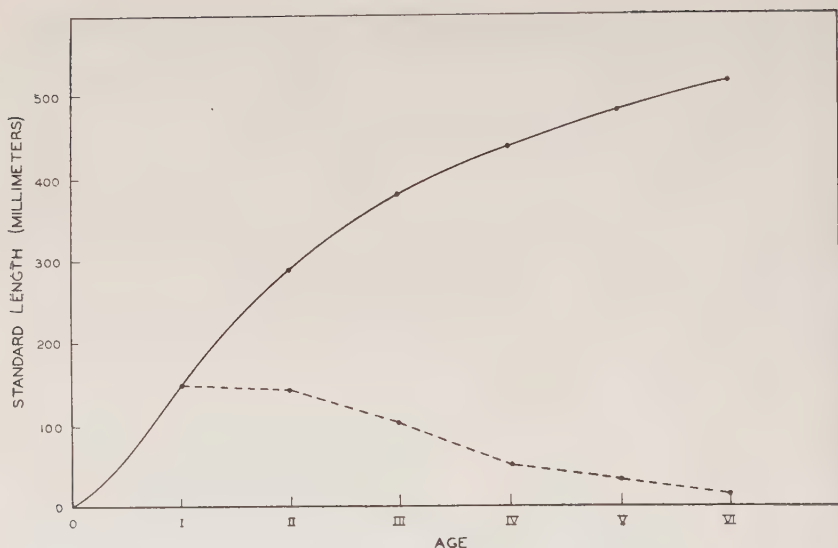


FIGURE 2.—The relationship between age and growth in length of Henrys Lake cutthroat trout.

TABLE 6.—Variation of growth in standard length (millimeters) within age groups from samples of Henrys Lake cutthroat trout collected from the lake and main spawning tributaries

Area, date, and age group	Length at capture, age group 0	Calculated length at end of year of life	
		1	2
Tributaries, 1951			
Hatchery Creek, August			
0.....	52- 66	.....	.....
Timber Creek, August			
0.....	36-103	.....	.....
I.....		76 115	.....
Duck Creek, August			
0.....	77 -108	.....	.....
I.....		156	.....
II.....			193-...
Targhee Creek, September			
0.....	125 141	.....	.....
I.....		180-...	.....
Lake, 1951			
0, August	126 175	.....	.....
I.....		140-260	.....
II.....		90-260	190-380

As might be expected, the variation of growth in length of cutthroat trout from different age-groups of the same year-class was less than the variation of growth in length of cutthroat trout from the same age-group of different year classes (Tables 4, 5, and 7). This difference in variation of growth in length between cutthroat trout of different year classes is attributed to the difference in environmental conditions in Henrys Lake and tributaries

TABLE 7.—Comparison of calculated standard lengths (millimeters) of Henrys Lake cutthroat trout, by year class, from samples collected in 1950 and 1951

Year of sample collection	Number of fish	Age group	Year class	Calculated length at end of year of life			
				1	2	3	4
1950.....	10	IV	{ 1946 {	117	267	378	421
1951.....	23	V		139	278	388	443
1950.....	18	III	{ 1947 {	131	263	364	..
1951.....	76	IV		133	278	384	..
1950.....	19	II	{ 1948 {	124	274	..	..
1951.....	96	III		136	277	..	..
1950.....	1	I	{ 1949 {	170	..	..	..
1951.....	76	II		163	..	..	..

TABLE 8.—Growth in length (millimeters) from end of last year of life to time of capture of 102 male and 124 female Henrys Lake cutthroat trout from the June-July 1951 sport-catch, by month, stage of maturity and age group

Age group	June				July			
	Male		Female		Male		Female	
	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature
I.....	50	..	63	..	81	..	75	..
II.....	43	30	33	..	77	60	52	..
III.....	..	19	26	3	..	18	38	23
IV.....	..	6	..	4	..	4	..	6
V.....	..	..	..	0	..	0	..	3
VI.....	..	..	..	0	..	..	..	..

between years. Time of ice-cover formation and break-up, frequency and intensity of cold wind-storms early and late in the season, and volume and time of the spring run-off in tributary streams are particularly good examples of the environmental factors that vary in Henrys Lake.

Differences of growth in length between immature and mature trout of the same and different sex and of the same and different age-groups demonstrates the retarding effect of attainment of maturity on growth in length (Table 8). This retarding effect of maturity on growth in length on male cutthroat is not so pronounced as on females, but most females have at least 1 more year of unretarded growth than do males.

The rate of growth in length of the average Henrys Lake cutthroat trout is most rapid during its first and second years of life, declines rapidly during its third and fourth years when maturity is attained and then tapers off gradually during its fifth and sixth years of life (Fig. 2).

LENGTH-WEIGHT RELATIONSHIP AND CONDITION

It has been shown by Hile (1936) that the length-weight relationship usually may be described by the equation:

$$W = cL^n$$

where W = weight in grams,
 L = standard length in millimeters,
 and c and n = constants.

The following equations were determined from empirical length-weight data from 351 Henrys Lake cutthroat trout by the least squares method:

$$\log W = -4.6353 + 2.9529 \log L,$$

$$\text{or } W = 2.316 \times 10^{-5} L^{2.9529}.$$

The length-weight relationship of the Henrys Lake cutthroat trout is shown by the curve of the above equations (Fig. 3) and the empirical mean and calculated mean weights are compared (Table 9).

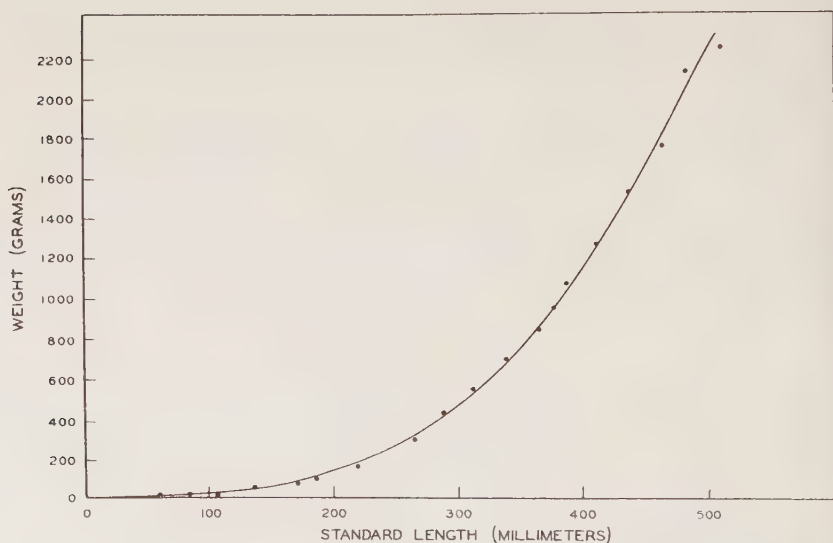


FIGURE 3.—Length-weight relationship of 351 Henrys Lake cutthroat trout collected in 1950 and 1951. Dots are based on the empirical means of Table 9.

The difference in the average condition factor (K) between immature and mature male cutthroat trout of age-group II and between immature and mature females of age-group III emphasizes the effect of initial attainment of maturity on growth and condition of the Henrys Lake cutthroat trout (Table 10). It should be noted, though, that even though growth in length of older cutthroat trout of age-groups IV, V, and VI was slow (Table 8), the condition factor (K) of these same trout was excellent (Table 10).

TABLE 9.—*Length-weight relationship of the Henrys Lake cutthroat trout, based on actual lengths and weights of 351 individuals collected in 1950 and 1951*

[The mean standard lengths are based on 25-millimeter intervals]

Mean standard length (millimeters)	Weight (grams)		Number of fish	Mean standard length (millimeters)	Weight (grams)		Number of fish
	Empirical	Calculated ¹			Empirical	Calculated ¹	
58	4	4	11	312	548	537	20
87	12	12	13	340	697	692	21
108	24	23	8	364	847	846	31
137	48	47	7	389	1060	1029	43
171	88	91	2	411	1251	1211	59
187	113	116	2	439	1514	1471	44
218	166	186	2	462	1745	1710	32
243	248	257	10	485	2114	1974	11
264	302	328	14	509	2233	2277	8
289	423	428	13				

¹ Calculated by use of the length-weight equationTABLE 10.—*Condition factor (K) of 102 male and 124 female Henrys Lake cutthroat trout from the June-July, 1951 sport-catch by stage of maturity and age group*

Age group	Male		Female	
	Immature	Mature	Immature	Mature
0.....	1.85	....	1.86	....
I.....	1.72	....	1.74	....
II.....	1.80	1.72	1.81	....
III.....	....	1.74	1.85	1.65
IV.....	....	1.78	....	1.80
V.....	....	1.83	....	1.80
VI.....	....	....	....	1.81

GROWTH IN WEIGHT

The growth in weight of the Henrys Lake cutthroat trout has been calculated (Table 11; Fig. 4) by application of the length-weight equation to the calculated lengths of Table 5. The rate of growth in weight continues to increase during the trout's second and third years, whereas the rate of growth in length declines after the first year (Figs. 2 and 4).

REPRODUCTION

Sex ratio.—The ratio of female to male cutthroat trout taken in the 1950 and the 1951 sport-catches declined not only with increase in age but also as the fishing season progressed (Tables 12 and 13). The sex ratio of the sport-catch for the entire 1951 season was 100 males to 110 females.

The large number of immature female trout taken in the catch during June and the greater number of mature males than mature females in the catch during the remainder of the season characterized the seasonal sex-ratio data of the sport-catch during 1951. Apparently, immature trout were more susceptible to the anglers' lures than mature trout during June be-

TABLE 11.—*Calculated weights and annual increments of weight (grams) for the Henrys Lake cutthroat trout collected in 1951*

[Computed by application of the length-weight equation to calculated lengths of Table 2]

Age group	Number of fish	Weight at capture	Calculated weight at end of year of life					
			1	2	3	4	5	6
0.....	9	57	...	.....	.....	.....	.....	.....
I.....	36	367	138	.....	.....	.....	.....	.....
II.....	76	781	79	487	.....	.....	.....	.....
III.....	96	1,168	46	378	917	.....	.....	.....
IV.....	76	1,503	43	382	991	1,432	.....	.....
V.....	23	2,023	49	382	1,021	1,511	1,891	.....
VI.....	1	2,466	10	247	1,118	1,799	2,161	2,357
Grand average.....			64	409	959	1,454	1,902	2,357
Increment.....			64	355	580	455	379	196
Equivalent total weight (pounds).....			0.14	0.90	2.11	3.20	4.20	5.20
Increment.....			0.14	0.78	1.28	1.00	0.84	0.43
Number of fish.....			308	272	196	100	24	1

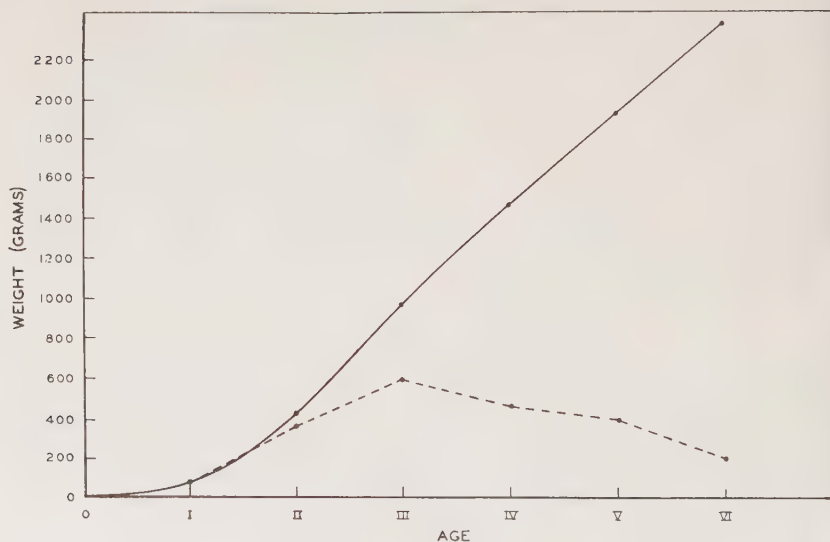


FIGURE 4.—The relationship between age and weight of Henrys Lake cutthroat trout.

cause, in all probability, the recently spawned mature trout were feeding less actively. Also, either the mature male trout were more susceptible to the anglers' lures than the mature female trout during the balance of the season or a greater mortality occurred to mature females than to mature males subsequent to the act of spawning.

Fecundity.—The fecundity of the Henrys Lake cutthroat trout varied with size during the 1953 spawning migration (Table 14). The fertility of over 11 million cutthroat eggs, taken at the Henrys Lake Spawning Station during the spring of 1950, averaged 93 percent.

TABLE 12.—*Sex ratio, by age-group, of the Henrys Lake cutthroat trout sport-catch for July of 1950 and 1951*

Age group	July, 1950		July, 1951	
	Male	Female	Male	Female
I.....	...	...	100	122
II.....	100	90	100	150
III.....	100	157	100	146
IV.....	100	25	100	32
V.....	...	...	100	57

TABLE 13.—*Sex ratio, by month, of the 1951 sport-catch of Henrys Lake cutthroat trout*

Sex	June	July	August	September	October
Male.....	100	100	100	100	100
Female.....	177	94	76	70	50

Spawning migration.—The spring-fed waters (46° F.) of Hatchery Creek are diverted through the Henrys Lake Spawning Station into a fish ladder which drains directly into the waters of Henrys Lake. The 1950 migration of cutthroat trout began the last week in March, reached a peak that followed the break-up of the ice cover on the lake in mid-May, and then declined rather abruptly during the following 2 weeks (Table 15). The male cutthroat trout were not counted but the majority of the males ran slightly earlier than the females.

That portion of the run which preceeded the break-up of the ice cover on the lake migrated primarily during the afternoon periods of the warmer days. After the ice cover left the lake, the maturing trout migrated into the trap night and day.

Natural spawning runs of cutthroat trout into other tributaries of Henrys Lake did not begin until the snow and ice cover melted from the streams in early May. These natural runs were of relatively short duration and were similar to the Hatchery Creek run after the ice cover left the lake.

FEEDING HABITS

During 1951, 116 stomachs were collected from cutthroat trout taken by trap, gill net, and hook and line. The stomachs were removed from the fish while fresh, wrapped in cheese cloth, and preserved in 10-percent formalin. Later, food items were washed from stomachs, measured, and sorted in a manner similar to that employed for the bottom- and plant-inhabiting organisms. Aquatic organisms utilized as food by the Henrys Lake cutthroat trout showed a greater qualitative correlation with organisms sampled from the plant habitat than with organisms from the bottom habitat (Tables 1 and 16).

Seasonal differences in food.—The midge-shrimp-damselfly food groups comprised 90 percent by number and 74 percent by volume of the food utilized by the Henrys Lake cutthroat trout during the study period.

TABLE 14.—Fecundity and size of eggs from large, medium and small female cutthroat trout selected at random from the Hatchery Creek spawning migration, 1953¹

Number of trout	Average standard length (millimeters)	Average weight (grams)	Average diameter of eggs (inches)	Average number of eggs per trout	Weight of eggs as percentage of total body weight
10.....	518	2394	0.200	2,930	9.8
10.....	408	1180	0.194	1,914	11.8
10.....	319	573	0.169	1,577	13.3

¹ Letter from Lee T. Hunt, Superintendent of Henrys Lake Hatchery, dated April 15, 1953

TABLE 15.—Weekly totals, daily averages per week and per month and the season total of female cutthroat trout that entered the Hatchery Creek trap during the 1950 spawning migration

Weekly period	Weekly total	Daily average per week	Daily average per month
March 28–April 3	290	41	37
April 4–10	278	40	
April 11–17	256	37	
April 18–24	155	22	
April 25–May 1	330	47	
May 2–8	500	71	
May 9–15	503	72	105
Lake ice-cover break-up			
May 16–22	1,034	148	
May 23–29	896	128	
May 30–June 5	398	57	
June 6–12	252	36	
June 13–19	119	17	37
Total	5,011	...	...

Larval and pupal forms of the midges, *Tanytarsus nigricans* and *Tendipes plumosus*, amounted to 35 percent by number and 10 percent by volume of the total diet. As many as 670 larvae were found in a single stomach as were 730 pupae. Midges were utilized to the greatest extent (88 percent) during the June-July period.

Consumption of the freshwater shrimps, *Gammarus lacustris* and *Hyalella azteca*, amounted to 27 percent by both number and volume of the diet. Individual stomach records show as many as 473 shrimp were taken by a single trout. Shrimps are utilized by the cutthroat trout throughout the entire growing season and are possibly its basic food item.

Utilization of the damselfly nymph, *Enallagma cyathigerum*, amounted to 28 percent by number and 37 percent by volume of the diet. As many as 1,445 damselfly nymphs were consumed by a single trout. To show the importance of availability as a factor that influences the cutthroat diet, the relation between the life cycle of the damselfly nymph and the feeding habit of the cutthroat trout will be briefly described.

Emergent vegetation is needed twice in the life of the damselfly. The

TABLE 16.—*Diet of the cutthroat trout from Henrys Lake, Idaho, during summer of 1951*
[Expressed as percentage frequency of occurrence in samples and percentages of volumes of food items]

Food item	Month of collection					
	June		July		August	
	Occurrence	Volume	Occurrence	Volume	Occurrence	Volume
Insects.....	80	32	97	82	57	16
Undetermined.....	13	3	34	4	5	2
Determined.....	80	29	97	78	57	14
Midge larvae.....	38	8	40	2	5	Tr.
Midge pupae.....	42	14	37	Tr.	10	Tr.
Mayfly nymphs.....	..	..	..	..	14	1
Water boatmen, adults.....	7	Tr. ¹	11	Tr.	38	10
Ant adults.....	2	Tr.	3	Tr.	..	..
Caddisfly larvae.....	2	Tr.	14	1	..	..
Caddisfly pupae.....	..	..	43	5	14	3
Caddisfly adults.....	..	..	9	Tr.	..	..
Damselfly nymphs.....	..	..	91	70	..	..
Amphipods.....	53	7	54	12	..	..
Cladocerans.....	42	34	54	57	..	1
Water mites.....	47	17	3	Tr.	24	5
Leeches.....	..	..	11	Tr.	..	..
Snails.....	11	2	12	4	5	Tr.
Sculpin.....	24	1	23	2	19	25
Cutthroat trout eggs.....	..	..	..	..	..	..
.....	9	14	..	..	..	..
Total occurrence and volume ²	45	249	35	304	21	15
.....					10	51

¹ Trace: volume percentage less than 0.5 percent

² Volumes in cubic centimeters

female, after fertilization of her eggs by the male, is towed along the surface of the lake by her mate until she comes in contact with and seizes an emergent stalk or flowering head of an aquatic plant. She then descends the stalk to some depth and lays her eggs. Since the flowering heads of the pondweed species of plants are emergent over most of the lake surface, eggs and thus the nymphs of the damselfly population are widely distributed.

To complete their life cycle, the damselfly nymphs must leave the water, emerge from their nymphal covering, and dry their wings before flight, as adults, is possible. The emergent portion of the pondweeds are subject to immersion by the slightest wave action and, therefore, do not always provide an adequate perch for the wing-drying process so essential to the successful metamorphosis of the damselfly. As a result, most of the damselfly nymphs migrate shoreward where they can shed their nymphal skins and dry their wings on more sturdy forms of aquatic or land vegetation. During 1951, this shoreward migration by the damselfly nymphs occurred in late June and early July. That the damselfly nymphs were most available during this shoreward migration is verified by the stomach records which show that 7 and 92 percent of the damselfly nymphs eaten by the cutthroat trout were taken during the months of June and July, respectively.

The water flea, *Daphnia* spp., ranked fourth by volume (7 percent) of food items. As much as 4.5 cubic centimeters of this important food organism were found in a single stomach. Cladocerans were the primary food of the cutthroat trout of Heenan Lake, California, but of secondary importance to cutthroat trout in Blue Lake, California (Calhoun, 1944). Hildebrand and Towers (1927) reported that *Daphnia pulex* was the basic source of trout food in Fish Lake, Utah.

Both the brook leech, *Nephrolopsis obscura*, and horse leech *Helobdella stagnalis*, were taken by the cutthroat trout. Several horse leeches, when immersed in formalin, regurgitated oligochaete worms of the species, *Limnodrilus claparedianus*. Thus, although *Limnodrilus claparedianus* inhabits the bottom muck and is therefore not directly available as food to the cutthroat trout, many were likely utilized via the horse leech.

Trout were seen feeding on the freshwater snails, *Helisoma subcrenatum*, *Lymnaea stagnalis jugularis*, and *Physa gryina*, when the snails were floating on the lake surface on foggy mornings. Although the freshwater snails amounted to only 3 percent, by volume, of the cutthroat trout diet, this kind of food amounted to 59 percent, by volume, of the diet of the rainbow × cutthroat trout hybrid.

Only one fish, a sculpin, occurred in the diet of cutthroat trout sampled from the lake habitat; however, cutthroat trout fingerling in the hatchery rearing pond occasionally fed on one another. One reidside shiner was recorded from the stomach of a Henrys Lake eastern brook trout. Mature individuals of both brook trout and cutthroat trout ingested eggs from their own species during their spawning migrations.

Terrestrial food was limited to a total of three ants in two stomachs.

Terrestrial insects comprised 17 percent, by volume, of the diet of the cutthroat trout sampled from streams tributary to the lake.

Seasonal trends in feeding intensity.—Sample collections of cutthroat trout stomachs were made throughout the day until 10 in the evening. Amount of food per stomach varied only slightly with time of day. Most stomachs were more than half filled and the stomach contents were exceptionally fresh in most samples. In fact, digestion had progressed notably in only 2 of the 116 stomachs. It would appear that the Henrys Lake cutthroat trout does not feed until the stomach is empty and then feeds until it is gorged.

The average number of food items recorded from stomachs of cutthroat trout during the summer months of 1951 were: June—172; July—218; August—16; and September—157. Not only was the number of organisms per cutthroat stomach relatively low during August, but only 62 percent of the stomachs sampled contained food. Since the average numbers of food organisms per sampling effort (food organisms of bottom dredge and townet samples) during the summer months of 1951 were: June—140, July—67, August—210, and September—230, the low feeding intensity during August could not be attributed to the lack of food. There is some evidence; however, that physical-chemical conditions may have been important.

Bishop (Bishop, *et al.*, 1950) explained that the normal activity of fish at various temperatures is related to rate of oxygen uptake; the higher the temperature maintained, the greater the oxygen consumption. At high temperatures and reduced oxygen tensions, the oxygen consumption falls off rapidly, indicating the inability of the fish to maintain the specific activity at the designated temperature.

The average surface and bottom temperatures and average oxygen tensions in Henrys Lake during 1951 were: 61° F., 57° F., and 8.4 p.p.m., in July; 68° F., 61° F. and 5.9 p.p.m., during August and, 56° F., 54° F., and 8.1 p.p.m., in September. The relatively high average temperature of most of the lake waters in combination with the relatively low average oxygen tension during August may account for the low feeding intensity of the cutthroat trout for that period.

Further evidence in support of this view comes from the fact that cutthroat trout were most available to the fisherman near areas of sub-surface springs or in mouths of tributary streams during August. In fact, during August, the successful fishing in Henrys Lake is restricted to these cool-water areas and the course of a school of trout moving into a cool-water area can be charted by the 'strikes' among a group of fishermen.

PREDATORS, PARASITES, DISEASES, AND MORTALITY OF UNUSUAL OCCURENCE

Predation was observed in only those areas where cutthroat trout congregated near the surface, such as at the mouths of creeks during the spawn-

ing migrations. The blue heron, kingfisher, and osprey were the major predators.

Gross examination of 116 cutthroat trout revealed one parasite, a larval form of the nematode, *Eustrongyloides* sp. It was found in a cyst just beneath the outer lining of the stomach. Identification of this parasite was made by Mr. J. T. Lucker, Bureau of Animal Industry, U. S. Department of Agriculture. Mr. Lucker said, "The adults of this nematode genus are parasites of fish-eating birds."

Eight of 256 cutthroat trout (approximately 3 percent) were infected with fungus. These infections were on the side of the body or near the caudal fin of the trout.

It is estimated that 3, 5, and 15 percent, respectively, of the mature cutthroat trout in the 1950, 1951, and 1952 migrations trapped at the Henrys Lake Spawning Station were infected with pathogenic bacteria. Toward the end of the 1952 season, as the water warmed, an estimated 50 percent of the trout in the trap were infected.³

External evidences of the bacterial infection were blisters just beneath the skin along the sides of the fish. The diameters of these blisters ranged from $\frac{1}{4}$ inch to more than 1 inch. Several of the infected cutthroat trout were examined by Mr. A. W. Klotz, Bacteriologist for the Idaho Department of Public Health. Concerning the pure cultures of the bacteria he developed, Mr. Klotz stated, "Cultures show gram negative bacilli resembling *Bacterium salmonicida* which commonly causes furunculosis in trout."

Although many trout with the large blisters were observed in Hatchery Creek and other tributaries during the spring of 1952, no trout with blisters or scars of healed blistered areas were observed in the anglers' creels. It might, therefore, be presumed that few trout survive infection by this pathogen.

During January 1952, an estimated 3,600 cutthroat trout of all age groups died in small open-water areas at the mouths of 3 tributary streams. The loss of these fish has been attributed to asphyxiation due to local oxygen depletion. A passing school of trout may have been attracted by warmer water or by light into these restricted areas from the ice- and snow-covered lake. No losses were reported from areas near stream mouths that were completely covered with ice and snow.

The mortality of the Henrys Lake cutthroat trout due to disease, asphyxiation, predation, and entry into the sport-catch plus mortality of mature cutthroat trout subsequent to the spawning act combine to prevent the individual cutthroat from reaching an advanced age and restrict the number in the population.

³ Estimates of infections by Lee T. Hunt, Superintendent of the Henrys Lake Fish Hatchery, in a letter to the author.

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Part 2
Panel Discussion

**PROBLEMS OF THE COMMERCIAL FISHERIES
CONSERVATION, TECHNOLOGY, ECONOMICS**

Presiding

VICE-PRESIDENT, Andrew L. Pritchard

Chairman of Panel

Richard Van Cleve, *School of Fisheries, University of Washington, Seattle, Washington*

Panel Members

Charles Ahladeff, *Whiz Fish Products, Seattle, Washington*

Edward W. Allen, *Allen, Allen, Froude, de Germa, and Leedy, Seattle, Washington*

Charles Carry, *Fisheries Products Division, National Canners Association, Washington, D.C.*

William C. Herrington, *Department of State, Washington, D.C.*

George Johansen, *Alaska Fishermen's Union, Seattle, Washington*

Robert Schoettler, *Washington State Department of Fisheries, Seattle, Washington*

PROBLEMS OF THE COMMERCIAL FISHERIES CONSERVATION, TECHNOLOGY, ECONOMICS

VICE-PRESIDENT PRITCHARD: It falls to my lot to introduce to you the Chairman of the panel on the various aspects of commercial fisheries. I would be somewhat presumptuous to give you a life history of Dr. Richard Van Cleve. This morning Dr. Schmitz pointed out the contributions which he, as one of the Directors of the School of Fisheries, had made to fisheries in the Pacific Northwest. All I can say is that those of us who have known Dr. Van Cleve over the years heartedly concur with Dr. Schmitz.

I notice too, as would be expected, that Dr. Van Cleve has arranged an extremely interesting panel. We have authorities on the administrative aspects of fisheries, on international law, on canning, on international relations, and on labor relations. Finally, we have a man who has been very prominent in the State and International Commission affairs.

I will turn now this session over to Dr. Van Cleve and his panel. Dr. Van Cleve.

CHAIRMAN VAN CLEVE: You can see from the membership of the panel that the fishing industry is very complex. As the fisheries have grown with the increase in size and population of this country the problems facing the industry have multiplied. The basic problem, of course, that the industry faces is that of conservation. The position of the United States in world markets is that of a buyer nation, and therefore imports of fish products as well as export markets present problems to the industry. We will mention these very briefly.

All these problems have added impetus to technological advances in both gear development and improvement in methods of handling and processing of the catch. Finally, the expansion of our fisheries into the high seas and of other nations' fleets into our own waters has raised important international problems.

We hope that in our discussion this afternoon two basic concepts will become clear. First, the use of all of our waters for the production of fish is very important to the United States as well as to the rest of the world. It will become more important in years to come as our population continues to increase. The second basic concept is that in the natural, just as in the cultivated fisheries, the best yield can be obtained only by harvesting that is carefully regulated in accordance with sound basic principles of biology and by the most efficient utilization.

Our first speaker, Mr. Johansen, can you tell us something of the economic importance of the fisheries in Alaska and along the Pacific Coast.

MR. JOHANSEN: The fishing industry in the United States, especially in the Pacific Northwest and in Alaska is of extreme importance to us for two reasons: First, it creates a lot of employment and wealth; secondly, it contributes to the national food supply. I think that most of you will

recognize, for example, that salmon is richer in protein than most meats. We in the Northwest and in Alaska are the principal suppliers of salmon to the national market.

In Alaska in normal times approximately 19,000 to 20,000 people are directly employed in the salmon industry. Here in the State of Washington we have 320 purse seiners on the Sound fishing for sockeye salmon—you have read about that recently in the papers. The crews average about eight men per boat which would give us a total of 2,560 fishermen on these boats alone. We also have about 600 gill-netters on Puget Sound, with approximately 1,200 people employed. We have about 650 or so trollers operating off the Coast that give employment to another 1,300 men. About 2,500 draggers are registered in the State of Washington and these boats carry a crew of about five. You can see that a lot of men are directly employed in this industry. To them must be added the cannery workers who process the product.

I am not going to talk much on the State of Washington because Mr. Schoettler is much more familiar with it than I am. I would like, rather, to comment on Alaska. Alaska, as you know, is one of the richest fish-producing areas in the world. As a matter of fact, there are fisheries that haven't been exploited; new fisheries could in time be developed. Some men have abandoned the fisheries for salmon, halibut, and herring, but the crab fishing and the shell-fish industry are just starting. No doubt they will in time develop to a point where they also will provide a lot of added employment and income in Alaska.

In normal times—from 1932 to 1941—we packed in Alaska approximately 6,400,000 cases of salmon per year. The pack, of course, declined in the next 10 years—1942 to 1951—to 4 million cases per year. We have the problems in Alaska of maintaining production; probably we will never completely solve it. The industry here on Puget Sound faces the same problem. This year we would say that the value of the pack from Alaska would run around \$90 million which means a lot not only to Alaska but to the people living in the State of Washington and in the other West Coast States. In Alaska this employment is the backbone of the commerce and certainly the problems in Alaska must be solved if the economy of the territory is not going to be seriously hurt. We will probably have to practice sound conservation before it is too late.

THE CHAIRMAN: Our next speaker, Mr. Schoettler, will comment on the importance of the fishing industry of the State of Washington.

MR. SCHOETTLER: I should like to start with the history of the fisheries of the Pacific Northwest, which goes back to about 1592 when the celebrated explorer, Juan de Fuca, discovered Puget Sound. After that time various explorers mentioned the local abundance of fish in this particular area.

In 1791, an equally famous Don Francisco Elisa came north for the purpose of taking back furs by having them put in tierces and salted. He was so overcome with the amount of salmon available in the harbor in

which he was anchored that he used some of the salt from the tierces and took back salted salmon instead. This same celebrated explorer named Port Angeles.

The Hudson Bay Company really began operating here in the Northwest in some volume in 1800 and by 1835 they were strongly in the "mild-cure" business, putting up tierces of salt salmon; about 4,000 barrels went out that year.

The fisheries of this particular area started about 1870, at Annaville, just off the mouth of the Fraser River. Our Canadian neighbors saw the value of the canned-salmon industry before our communities were able to develop it.

It would be interesting to go into some of the history of the boats and equipment. As you know, the first power boats came into the fisheries around, I believe, 1904. Prior to that time everything was sail. The oldest type of gear was the reef net. It is an Indian method in which you set a net on a reef and take the fish as they surface to go over the reef. We also had the beach seine. Next came the trap and along with it, the fish weir. A later introduction was the lampara seine—a Mediterranean seine—which was developed into the round-haul seine.

Changes have occurred also in materials and methods of handling gear. First we used cotton, then linen, and now, of course, nylon; the efficiency of the gear has risen tremendously with these improvements. We have introduced the leader, the purse seine, and the drum seine in which the entire seine is handled by a drum.

The first motors that went into the vessels were gasoline engine, only 24 to 30 horsepower. Our purse seiners today have equipment of, say 132 horsepower, and the horsepower of the engine in an average gill-net boat is 100.

THE CHAIRMAN: Could you give us something on the value of the fisheries here in Washington?

MR. SCHOETTLER: Contrary to the belief of many people the fisheries of the State of Washington are quite large. Salmon are best known because everybody likes to catch them and because they are a beautiful fish. Many don't realize the importance of other fish in this State.

We have bottom fish or flatfish and round fish. Salmon are, of course, most important. The purse seines took about 6½ million salmon last year; gill-netters about 1,800,000; reef-netters about 687,000; trollers, 1,200,000. In addition the Indians took a half-million pounds.

Among our bottom fish is the halibut of which over 14 million pounds are landed here. I should mention also black cod, flounders, sole, lingcod, rock cod, and true cod, of which we last year took 28½ million pounds.

Another fish of which little is heard is the smelt. It occurs only on the Columbia River where both Washington and Oregon participate in the fishery. The catch off the Washington side of the river amounted to more than a million pounds last year. Our catch of herring amounts to over 500,000 pounds. We also take a quarter-million pounds of sturgeon and

167,000 pounds of shad. Then we have scrap fish, used for mink food and reduction purposes, in the amount of $1\frac{1}{2}$ million pounds.

The value of the fishery production in Washington in 1953 is estimated at \$37,687,000.

THE CHAIRMAN: We see that the fisheries do produce quite a bit of food, but how about the utilization of that food, Mr. Carry? Can you tell us something about the position of the United States in per capita consumption of fish?

MR. CARRY: Consumption of fish in the United States for the last year for which figures have been available was about 11.6 pounds per person. That figure is very moderate as compared to consumption of fish in Japan, Norway, and some of the more noteworthy fish-eating countries. Strangely enough, if we could increase our consumption by 1 pound per person I think we would have a scarcity of fish in the United States.

THE CHAIRMAN: Mr. Herrington, you were in Japan for several years after the war. Do you have any remarks to make concerning the relative importance of fisheries there so that we might get some sort of preview of changes we can expect here as our population density increases?

MR. HERRINGTON: Many of us grew up with the idea that the United States is the principal fish-producing country in the world. Actually, we produce between 4 and 5 billion pounds annually. Japan even now produces around 8 to 9 billion—approximately double our production—and they are rapidly expanding their fisheries.

Fish occupies a very important place in Japanese diet. In this country we get roughly 90 percent of our animal proteins from agricultural production and 10 percent or less from fisheries. In Japan these figures are reversed; they get some 90 percent of their animal protein from their fisheries and 10 percent from agricultural products. The Japanese make full use of the fishery production, eating practically everything they catch. The Japanese diet probably represents about the extreme in utilization and consumption of fishery products.

THE CHAIRMAN: You have given us an idea as to what may occur in the future. However, it will be some years before our population density approaches that of Japan, but from the numbers of children we see it looks as though that time may be nearer than we suspect.

Mr. Alhadeff, will you tell us something about production and marketing of fish?

MR. ALHADEFF: Industry—the buyers, the packers, the distributors—have the responsibility for providing food product to the home that must be both acceptable and desired. It is doubtful whether any other food product in the whole world is so highly perishable and needs such rapid, careful attention as is required by fish. The fisheries have often been classified as a primitive industry. It was possibly so historically, but the fisheries in the United States has kept pace with progress.

Let us consider several fields of progress which indicate fishery advances. The changes in fishing methods, the transition from sail to gasoline engines and then to Diesel, changes in materials used in nets and in methods of operation,—those are all indications of progress along with other industries. Most important of all have been improvements in sanitation and sterilization, because a highly perishable product must continuously be handled with great care to prevent spoilage and protect quality.

We have, of course, faster boats and faster delivery to the plants. We have developed faster machinery for canning and have improved quick-freezers.

In addition to these fast methods of freezing and canning we have developed better systems of distribution. The past decade has seen tremendous advances in consumer packages and other types of fishery preparation so that we can deliver to the housewife a package of fish that is acceptable.

THE CHAIRMAN: We see that the techniques of handling fish have changed rapidly. What are some of the most important recent developments in this line?

MR. ALHADEFF: I would say that putting the fish into a consumer-sized package has possibly been the greatest development in fish distribution. This improvement has been made possible by the advancement in refrigeration, both in the stores and in the homes. Packaging has increased the per capita consumption of fish in the United States tremendously.

The most spectacular results have come from the introduction of fish sticks. During the first 6 months of 1953 approximately 100,000 pounds per month were produced. During the second 6 months of 1953 almost a million pounds per month were produced and distributed. During the first 6 months of 1954 we have produced almost 4 million pounds per month.

Fish sticks are cut so as to be 1 inch each way in thickness and about 4 inches long. They are cut from frozen fish and breaded. Often they are cooked, then frozen in packages of 12 ounces or 1 pound each and distributed through the freezer cabinets. Possibly 90 per cent of the production is in that form. All that is required is heating in the oven.

THE CHAIRMAN: Mr. Carry, will you please review recent developments in the canning industry?

MR. CARRY: Our most spectacular development took place perhaps 75 years ago when we really learned how to can foods, but since then we have been moving along slowly. However, we have been moving. For example, the number of cans we pass through a closing machine is 240 per minute—sometimes more. A few years ago 60 per minute was a good figure.

We have also eliminated the so-called "exhaust box" from the canning line which tended to cook most products a little bit more than was needed. We have substituted the vacuum closing-machine that does practically the same thing and retains that delicate flavor that we all know exists in fish.

Another development that might help put me out of business just as much as fish sticks is the preservation of food with radioactive materials.

The procedure, of course, is for the future. We don't know how soon it will be feasible or practicable but it is being studied intensively now.

MR. HERRINGTON: Mr. Alhadeff referred to fisheries as a primitive industry. The reason, I think, is that primitive man depended on hunting. As he progressed he moved gradually into a sedentary agricultural economy and didn't have to wander. Now, isn't the catching of fish primarily a matter of hunting? What is the fishing industry doing to change this hunting economy into some other kind of economy?

MR. ALHADEFF: Fishing is a primitive industry. Going after fish is hunting and the more sea-scanners, the more depth finders we have, the more highly skilled and efficient the fishermen become, the less chance have fish. The fishermen and the industry as a whole have a responsibility to perpetuate the industry and you can't perpetuate the industry if you over-exploit the resource.

In my opinion the industry is cooperating towards this perpetuation of the fisheries. Often we have helped to create commissions and authorities, both by financial aid and by pressure on Congress. We want to be governed by proper regulations in the United States, as well as Alaska—regulations which have been properly considered and based on proper biological research. Does that give you the answer?

MR. HERRINGTON: I think that is a good answer. The Halibut Commission and the Salmon Commission have placed those industries beyond the hunting stage. With farm-pond management we are going beyond the hunting stage. In short, we are rapidly progressing from a primitive economy to a managed economy.

THE CHAIRMAN: Mr. Carry, would you care to discuss the problem of imports?

MR. CARRY: Without question we do have a problem with imports into the United States at the present time, but ours is part of a world problem.

Mr. Herrington mentions primitive fisheries, but fisheries are not primitive in many countries. In some they are perhaps more advanced than in the United States or in Canada. Some countries with advanced fishing methods need money to buy things they can't produce themselves; they have something to export. One of their principal export items happens to be fish. Those exports get us into trouble occasionally; we can absorb a certain amount of their exports, but there comes a time when it begins to hurt just a little bit.

We have in this country various social welfare laws that require our businessmen to pay their employees certain minimum wages. No other country that I know of has exactly the same sort of system. As a result, we are at a decided disadvantage since labor is an important element in the cost of processing.

We can take tuna as an example. It costs a lot of money to catch tuna. The Japanese people can produce tuna for a considerably lower labor cost than we, and they have been sending their tuna into the United States to the disadvantage of our own industry.

Don't misunderstand me. We are not trying to exclude anybody from this market; we are only trying to contain the imports within reasonable bounds so that our own industry can continue to prosper. Tuna production by U. S. fishermen has grown from approximately 2 million cases per year in 1941 to 9½ million cases last year, and this year the catch is expected to be over 10 million cases. Now, you don't just produce tuna and not sell them; you have to develop a market. We have developed a market in the United States by the expenditure of a considerable amount of money and the Japanese industry has reaped much of the benefit of that advertising program.

The same is true of a number of other items. There are some, however, that we cannot produce in the quantities needed in the United States to supply the demand.

THE CHAIRMAN: Mr. Alhadeff, how about exports?

MR. ALHADEFF: We are basically an importing nation in so far as fisheries are concerned. We do export limited amounts of such things as sardines and oils, but such fish as cod, halibut, salmon are consumed in the United States, never exported.

MR. HERRINGTON: We often hear the remark that the solution of the import problem is to increase consumption. I believe the people who make that statement fail to appreciate the overall problem of imports. It is a fact that the United States is the principal, and in some cases, the only market for certain fish products. Shrimp is probably the outstanding example. Last year we imported shrimp from nearly 30 different countries, and reports come in from all parts of the world that many, many countries are seeking new sources of shrimp production, primarily for export to the United States. If you can expand your market fast enough to absorb this increased import you can maintain the price level in the United States so that our fishermen can compete, if you can't, the price will drop.

We are also practically the only market for canned tuna. We are the principal market for frozen ground fish. Many countries are developing their fisheries and freezing more fish to ship to the United States. Whether we can increase consumption in the United States fast enough to keep the price from dropping below the level where our fisheries can compete is questionable.

Questions of international relations enter the problem of imports of fishery products. The United States is the leader in a struggle which will determine our fate and the fate of our children. The United States is very much interested in maintaining the economy, the prosperity of the free world. Unfortunately for the fishing industry, it happens that a number of countries which are critically important in this struggle are in a much better position to export fish than other products. The fishing industry, then has to take the brunt of this overall policy. Our fishing industry is indeed faced with serious problems in the question of import.

MR. CARRY: I should like to comment on Mr. Herrington's remarks. I want to point out that this concern with the economic welfare of some nations is just a little bit overdone. I do not believe that our good friends

in the international community would desert us just because we wanted to protect our own industry to a moderate degree.

MR. JOHANSEN: We cannot compete with foreign labor in the fisheries; consequently importation is going to do some harm to our own industry. We are aware of the policy of the United States in upholding the economies of various nations that sell fish to the United States. Nevertheless, our own economy is at stake, and for the fishing industry the stake is big. It involves a lot of employment and capital investment. We feel that if the Government must protect the economy of fish-producing nations that are in direct competition with the United States fishing industry, then we ought to be entitled to some kind of subsidy similar to that given agriculture. We are in the food-production business too. I think there is a need for a better understanding of the effects of policies of the United States as they relate to our own fishing interests. We do not believe that our industry should be destroyed to support foreign policy.

THE CHAIRMAN: It has been mentioned that fishing on the high seas involves international relations. Mr. Allen, would you explain how the subject of foreign relations is important to our fishing industry?

MR. ALLEN: I think one of the best illustrations is the Pacific Coast halibut industry. Halibut are found on banks of limited depth and limited water temperatures; they are limited therefore in area, along the coast from northern California into the Bering Sea.

You are all familiar with the 3-mile rule which is advocated by our own Government, namely that this country owns a strip of water 3 miles wide along its entire coast. Other countries claim different widths; the Scandinavian countries claim 4 miles, some countries claim 6, some of the Mediterranean countries and some of the South American nations are making very extravagant claims of ownership of water along their coasts.

Now, about 10 percent of our halibut catch is inside of that 3-mile limit. About 90 percent of our halibut catch, therefore, is taken in waters of which we do not claim to be owners. In addition to being inside and outside of territorial waters these fish go north along our coast and don't seem to know where the boundary is between British Columbia and the State of Washington on the south or Alaska to the north.

Another interesting case is the sockeye salmon. Those fish spawn primarily in the Fraser River. They come in through the Straits of Juan De Fuca between Vancouver Island, which is a part of British Columbia, and the Olympic Peninsula, which is a part of the State of Washington. Then usually they swing south of the San Juan Islands which belong only to the United States, move through Rosario Strait which is wholly within the United States, past Point Roberts, which is within the United States, and thence on up into Canadian waters in the Gulf of Georgia and into the Fraser River.

Fish like halibut and salmon do create international problems. How is the State of Washington to regulate the halibut fishery off the British Columbia coast? How is British Columbia going to regulate the sockeye

salmon fishery when these fish come through the San Juan Islands which are in United States waters? Only by international cooperation can these fisheries be regulated.

We have the further problems with salmon in the Bering Sea and south of the Aleutian Islands and Komandorsky Islands. At the present time nobody knows just how far our Alaskan salmon go toward Siberia or how far east the Siberian salmon come toward our coast. Siberia has annual salmon runs of the very same species that we have in Alaska. Japan has an additional species, not very numerous, but Siberia, Alaska, and our Pacific Northwest all have identical species. Are these fish stocks independent? Can a line be drawn between the Asiatic and North American salmon? If not, what are we going to do to give those salmon the necessary protection?

VICE-PRESIDENT PRITCHARD: Another problem of great importance involves the entire Columbia River watershed. Here, I believe, a compact exists among the States of Oregon, Washington, Idaho, and Montana.

MR. SCHOETTLER: The lower Columbia River basin compact which is just being formed will involve seven States. We have a fishery committee and I believe some of the members are here today. I understand that when the compact is concluded, it will contain a section regarding fisheries that will give excellent protection for the States of the interior as well as the coastal States.

THE CHAIRMAN: On the Pacific Coast we have the Pacific States Marine Fisheries Commission which involves the three coastal states, California, Oregon, and Washington.

Mr. Herrington, will you describe to us some of the other international problems facing our commercial fisheries?

MR. HERRINGTON: I would like to talk a little about the problem of the extent of territorial waters which Mr. Allen mentioned a few minutes ago. The 3-mile policy long had world-wide acceptance, but of late it has been challenged. As recently as 1930 most nations accepted 3 miles: a few claimed 4 and even fewer 6. Much greater claims are now made.

This is a long-range problem and one of great importance to the fishing industry. Decisions made will affect greatly such fisheries as those for shrimp and tuna. At stake also is the general concept of freedom of the seas. It is indeed, from the point of view of the United States, an extremely important problem.

Why are nations in these last few years attempting to overturn time-honored philosophies under which the world has been living and which we think have been beneficial. One of the more important factors is the conservation of resources. As most of us use the term here conservation means wise use for maximum productivity over the future, but there are other meanings of conservation. In Spanish it means to conserve for one-self. To some nations, then, conservation of resources means they must have them for their own use; it means ownership.

These nations see the far-ranging fleets of other nations fishing on the high seas off their coasts. They believe, not truly, but honestly, that these fleets will catch all the fish in the area so that at some future date when they wish to send their own fleet out on the high seas no fish will be left. To prevent such a development they feel they must claim control to end operations of the foreign fleets.

Another reason for the claims is the desire to tax the fishing fleets of other countries to add to their own national income. In some cases national pride is a factor.

Generally, these nations fail to see the consequences of their actions. If a country can claim 50 miles or 200 miles, it can claim 1,000 miles and then the freedom of the seas is lost. The countries who have the power will then very likely control the seas. It is easy to see why this matter has occupied the attention of an increasing number of international bodies.

The International Law Commission which is a body of the United Nations has had this matter under study for some years as have also the Council of Europe and the organization of American States. The International Court of Justice has had one case between the United Kingdom and Norway and now a case is pending between Australia and Japan.

The United States holds that we have a better chance of solving these problems if we take them up step by step as we have done with other conservation problems. Our first step in this direction was the halibut treaty of 1925. This treaty and the others that followed have shown how to handle international problems of fisheries on the high seas. We think this procedure can be applied on a world-wide basis. We have put the problem on the agenda of the next meeting of the United Nations. We have also put on the agenda an item regarding the continental shelf.

MR. ALLEN: I think that Mr. Herrington covered the subject very nicely but he did not bring out a few points that are particularly important to our fisheries here in the Northwest. In this matter of the width of territorial waters, there hasn't been uniformity of view even in the United States. There was quite a movement, for instance, in the 1930's to extend the width of territorial waters of this country. The basis for that movement was the fact that this country either alone or in conjunction with Canada, has actually expended millions of dollars in studying our fisheries and in protecting them. We are making practically full utilization of them. If other nations were to enter those fisheries they would not increase the catch but they would injure the stocks. You can't expect our fishermen to be enthusiastic about assistance in exploiting stocks we have restored and protected. It is not surprising that in the 1930's many recommended extension of the boundaries of our territorial waters.

Although our Government has been pretty solidly committed to the 3-mile doctrine, there is another doctrine of international law which holds that a coastal nation may have special rights in the sea which extend beyond its ownership. In other words, even though we only own 3 miles in coastal waters, our rights may extend even beyond that line. This

principle has been recognized for generations in the case of quarantine, customs control and similar matters. There has also been recognition in the case of fisheries. England was the first country to claim exclusive rights in certain fisheries beyond the 3-mile zone. Because of those claims our fishing industry began to urge our Government to recognize this established principle of law as applicable to our salmon and halibut.

In connection with this problem, I might say that the treaty with Japan that we ratified in 1953 recognized this principle. The treaty provided that a nation which exclusively, or two nations which together scientifically investigate and regulate a fishery to make substantial maximum use of the fishery, have an exclusive right to that fishery.

The situations in the fisheries of this general area and of the tuna fishery are different. Our Northwest fisheries have been developed exclusively by ourselves and Canada and have been subjected as a result of investigation to regulation for maximum use, whereas the tuna fisheries to the south were not developed by South America or Central American countries. They were developed by our own California tuna fishermen, which makes an entirely different situation. I think it should be understood that we, the United States, may have to resort to asserting this principle of international law if other nations interfere with our own coastal fisheries to a detrimental extent.

MR. HERRINGTON: A short time ago I said that we would like to apply some of the principles worked out in the North Pacific on a broader scale. We think a number of high-seas problems can be handled similarly and I think that even Mr. Allen may agree that perhaps in the long run international cooperation is the better solution. Development of an official United States position has been difficult because we have within our borders probably as great extremes as you will find within any country in the world. I think, nevertheless, that we finally worked out a position that meets the problems here. The principle of international cooperation should be applied on a much broader basis.

MR. CARRY: We also have an international compact that deals with the North Atlantic and involves 10 nations. Within the United States this treaty is whole-heartedly supported by the States that have principal concern with the area.

We also have, thanks to Mr. Herrington, a Great Lakes Treaty signed though not yet ratified, and an international agreement with Costa Rica and now Panama to investigate tuna. We have further by state compacts the Atlantic States Marine Fisheries Commission, and the Gulf States Marine Fisheries Commission. All of these indicate to me that not only is the Northwest aware of the general subject of intelligent management of fisheries; the rest of the country is as well.

MR. ALHADEFF: As members of the fishery industries we work directly with the Pacific Salmon Commission and the Halibut Commission. We have very positive evidence of the practical value of their work. If the Commission is government, we can, will and do work with government.

I brought that point out because we have the North Atlantic Commission, the Tuna Commission recently put in operation. This morning I heard that the States in the Great Lakes area, with the Province of Ontario on the Canadian side, have supported a treaty to create a commission. I would like to state that the lake states and provinces should be congratulated in making that tremendous step.

THE CHAIRMAN: I would like to ask Mr. Johansen how the fishermen feel about the problem of conservation.

MR. JOHANSEN: I would like to open with a statement about the Halibut Commission. According to the Commission's figures almost 70,000,000 pounds of halibut were caught in this year. In 1918, the previous record year, the catch was $68\frac{3}{4}$ million pounds. Then the production went down and down and down and reached a low about 1931. Now, we have come back to a point where we have exceeded the previous record and I think this is wholly to the credit of the Commission who, through good regulations, have made this recovery possible. Certainly both labor and industry owe the Commission a vote of thanks. The people who actually do the fishing have helped by keeping accurate logs and reports that help make it possible to establish good regulations.

In Alaska where we have in later years been faced with a very serious decline of the salmon runs, the conservation problem has become acute. Both the unions and industry are interested in keeping the fishery at as high a level as possible, and they are certainly interested in protecting this industry from overexploitation. For that reason both management and labor have taken a very active interest in conservation problems.

The industry and the unions have at various times petitioned to the Congress and have supported moves to set up these various commissions which have proved so beneficial.

In addition, we have, in our contracts with industry, written in clauses setting fines for our members who willfully and knowingly violate the regulations. We realize that the few fish that might be gained by illegal means today will mean a much greater ultimate loss in the future.

As for the activities of the industry, we find that in the Bristol Bay area, the Alaska Salmon Industry, Inc., expended \$650,000 between 1945 and 1954 on research on the salmon resources of that region. This money was made available to Dr. William F. Thompson for his use as he saw fit to benefit conservation. The industry has also, in Southeastern Alaska, Kodiak, and in other places, spent an equal amount in trying to find out what could be done to increase the yield of the salmon runs. If any of you have had the idea that the commercial fishermen and the industry have no concern or interest in conservation, you have been mistaken because we definitely are concerned. Our living depends on the fisheries.

As you all know, the Fish and Wildlife Service has control of Alaska fisheries. We hope that the new leadership of the Fish and Wildlife Service will take a different and a more realistic approach, that more research

can be undertaken in the Alaska fisheries to find the cause of the downward trend and the means to bring the runs back. We believe that not only must scientists be on the job, but also that we must have men who can direct the scientists in the way that their work can do the most good.

We believe there should be complete cooperation among all research agencies, the various unions, and the industry. We believe sincerely that work along those lines will certainly go far toward finding the solution and that our salmon runs in Alaska will return to and exceed former levels.

THE CHAIRMAN: Mr. Allen has a few remarks to make.

MR. ALLEN: I think it might interest you to know that the cooperation of the halibut fleet itself has been one of the genuine reasons for the success of the Commission. The Commission itself set up a conference board consisting of representatives of the fishermen's unions in the halibut fishery and of the vessel owners. Every year before it makes the regulations the Commission calls this board into session for consultation and advice. The Commission then formulates its regulations, and the result of the intimate association with industry and the absolute frankness of discussion has been the closest cooperation.

THE CHAIRMAN: I think we have fairly well covered the major problems before us.

I want to take this opportunity to thank the members of the panel who have given their time to come here and who have also spent a great deal of time, I can assure you, in preparation for this afternoon's discussion. I appreciate very much their cooperation and I want to thank each of them individually. I also want to thank the members of the Society for their attention. I now turn the meeting back to Vice-President Pritchard.

VICE-PRESIDENT PRITCHARD: Thank you, Dr. Van Cleve. I should now like to permit the audience to ask any questions they would like.

MR. FARLEY: I don't know whether this is a question or just a little addition to the discussion but I had hoped that in the panel discussion something would be said about what in my judgment marks one of the high spots of last year's attainments. That is the passage by Congress of the Saltonstall-Kennedy Bill providing funds for research. I suppose you all know of this legislation but I would like to emphasize that it marks the first time that I have seen representatives of the fishermen, of the canners, of the States, of everybody here at this table and many others all giving practically the same statement in urging the passage of the measure. We need more facts, we need greater research if we are to manage our fishery resources in a proper manner. As a result of united, constructive, enlightened thinking we have now available \$3 million annually for the next 3 years. I say we because it includes all of us, both the Fish and Wildlife Service and other people interested in research—both basic biological research and technological research.

Approximately two-thirds of the first year's funds have been programmed. The remaining one-third is waiting several developments. One is the appointment of an advisory committee; another, a meeting of the North Pacific Fisheries Commission which takes place next month. It seems to me that it is a great day, a really great day, for the members of this Society when industry, labor, educators, and legislators all unite and without one word of disagreement say, "We need more fishery facts in order to manage our fisheries properly."

THE CHAIRMAN: We appreciate the great importance of the bill that was passed. Are there any further questions or comments?

MR. JOHANSEN: We certainly are in agreement with you, Mr. Farley, that this is one of the most important pieces of legislation in so far as the fisheries are concerned that we have ever had. There was strong support by both the unions and the industry for the passage of the bill. We all knew that it was needed desperately, particularly because research is needed in Alaska.

I believe that the Fish and Wildlife Service has a great responsibility to use that money where it is most needed. If there is any waste, if there is any boondoggling, any careless spending of this money, it will react against us and we will find it hard in the future to derive such benefits as we did through the Saltonstall-Kennedy Bill. In our opinion this fund should not be allocated because of any political consideration and an honest attempt should be made to find out just exactly what is needed. I do hope that you, as Director of the Fish and Wildlife Service, if you have anything to do with the allotment of this money, will do your best.

MR. FARLEY: I am glad to give you assurance that with Saltonstall-Kennedy money, with regulations for the Alaska fisheries, with any problem, only one question is asked in the Secretary's office: "In your judgment, is it the right thing to do?" I have been working in a refreshing atmosphere. I see no reason for concern that it should be changed.

THE CHAIRMAN: I am sure that anybody who has negotiated any contracts with the Fish and Wildlife Service is soon aware of their careful use of funds. Any more questions? If not, I will turn the meeting back to you, Dr. Pritchard.

VICE-PRESIDENT PRITCHARD: I would like to thank you, Dr. Van Cleve, and your panel for what I consider a most excellent discussion of the problems facing commercial fisheries, mainly in this region. I realize that you have restricted yourselves because you couldn't cover all areas.

This afternoon we find ourselves facing new conditions. Money is being made available and apparently we are getting results or that money wouldn't be given to us. Cooperation is improving and I feel that we are now starting a new era of fishery management. I would like to say, if the biologists will forgive advice from a man who is no longer a biologist, that this situation places an extremely heavy responsibility on you. You can't

afford to fail. As an administrator, I would like to say that we also have a responsibility and I sincerely hope that both groups will be able to carry the load and that in another 26 years when we will be able to say that we discharged the responsibility, that our fisheries are in much healthier condition than they were or are now—because they can be better.

Dr. Van Cleve, I extend the thanks of the audience and certainly the thanks of the Society for the work that you people have done—for the extremely fine presentation that you and your panel have made this afternoon.

Part 3
Business Sessions

THE AMERICAN FISHERIES SOCIETY

EIGHTY-FOURTH ANNUAL MEETING

The eighty-fourth annual meeting of the Society was opened in the New Washington Hotel, Seattle, Washington, at 9:00 a.m., Monday, September 13, 1954. The agenda were as follows:

Monday, September 13

Morning: Address by the President; roll call of members; action on nominations for membership; introduction of noteworthy guests and visitors; address by Dr. Henry Schmitz, President, University of Washington; appointment of sessional committees; reports of officers, chairman of regional divisions, standing committees, and special committees.

Afternoon: Panel discussion on various aspects of commercial fisheries.

Tuesday, September 14

Morning: Presentation and discussion of papers.

Afternoon: Presentation and discussion of papers; reports of sessional committees; election of officers, installation of the new President; concluding business.

Wednesday, September 15

Morning and Afternoon: Tour of local points of interest.

Evening: Annual joint banquet—Windsor Room, New Washington Hotel.

REGISTERED MEMBERS IN ATTENDANCE

Aldrich, A. D., Okla.
 Allen, Edward W., Wash.
 Allen, George H., Wash.
 Allen, Walter M., Mont.
 Aron, William, Wash.
 Atton, F. Mervyn, Sask.

Bagley, Lester, Wyo.
 Barry, James V., Wash.
 Bates, Daniel W., Calif.
 Baxter, William, Del.
 Bayliff, William H., Md.
 Beatty, Robert O., Ore.
 Beckman, R. W., Iowa
 Bode, I. T., Mo.
 Bond, Carl E., Ore.
 Borovicka, Robert L., Ore.
 Boussu, Marvin F., S. D.
 Boyd, Hubert H., Wash.
 Buck, D. Homer, Okla.
 Butler, Frank R., B. C.
 Butler, George E., Man.

Calhoun, Alexander J., Calif.
 Callison, Charles H., D. C.
 Campbell, Charles J., Ore.
 Campbell, Robert S., Mo.
 Carlander, Kenneth D., Iowa
 Carry, Charles R., D. C.
 Carufel, Louis H. Jr., N. D.
 Chin, Edward, Mass.
 Clark, Ernest D., Wash.
 Clark, Minor E., Ky.
 Clemens, Wilbert A., B. C.
 Cobb, Roland H., Maine
 Coots, Millard, Calif.
 Cornell, James H., N. C.
 Couldwell, George E., Sask.
 Cross, Frank B., Kan.

DeBoer, Marston J., Mich.
 DeLacy, Allen C., Wash.
 Dickson, Fred J., Ga.
 Dimick, R. E., Ore.
 Donaldson, John R., Wash.
 Donaldson, Lauren R., Wash.
 Doudoroff, Peter, Ore.
 Dunlop, Henry A., Wash.

Eicher, George, Wash.

Farley, John L., Va.
 Foerster, R. Earle, B. C.
 Foster, Richard F., Wash.

Franklin, Donald R., Minn.
 Fredin Reynold A., Wash.
 Fukano, Kiyoshi G., Mich.

Garlick, Lewis R., Ore.
 Gaufin, Arden R., Utah
 Gensch, Robert H., Mont.
 Gentry, Glenn, Tenn.
 Glude, John B., Maine
 Gordon, Seth, Calif.
 Greenbank, John, Colo.
 Greene, A. F. C., Wyo.
 Griffith, George A., Mich.
 Gunning, Gerald E., Ill.
 Gutmuth, C. R., D. C.

Halferty, G. P., Wash.
 Hall, Gordon E., Okla.
 Hanavan, Mitchell G., Wash.
 Harkness, William J. K., Ont.
 Harmic, Jay L., Del.
 Haydu, Eugene P., Wash.
 Hazzard, Albert S., Mich.
 Held, Edward E., Wash.
 Hemphill, Jack E., Ariz.
 Herrington, William C., Va.
 Hickman, Cleveland P. Jr., Wash.
 Hildebrand, Henry H., Texas
 Hile, Ralph, Mich.
 Holland, Gilbert A., Wash.
 Horton, Howard F., Ore.
 Huestis, E. S., Alta.
 Hunter, William F., Mich.
 Hutchinson, Samuel J., Ore.

Jackson, Fred W., Colo.
 James, Milton C., Wash.
 Jeppson, Paul W., Idaho
 Jewett, Stanley G., Jr., Ore.
 Johnson, Fred W., Mont.
 Johnson, Raymond E., Minn.
 Joslin, Verne E., Minn.

Kask, John L., Ont.
 Katz, Max, Ore.
 Kauffman, Donald E., Wash.
 Kautz, Richard A., Wash.
 Kemmerich, Alphonse, Ore.
 King, John, Okla.
 King, Willis, D. C.
 Kinney, Edward C. Jr., Ohio
 Koo, Ted S. Y., Wash.

Lagler, Karl F., Mich.

Lander, Robert H., Wash.
Larkin, Peter A., B. C.
Larson, Ralph W., Wash.
Lavie, Dorian C., Wash.
Lawrence, William M., N. Y.
Leik, Thomas H., Colo.
Lewis, Lawrence J., Mich.
Luethy, Don R., Fla.

MacKay, H. H., Ont.
Madsen, M. J., Utah
Maher, Frank, B. C.
Mason, James E., Wash.
McBroom, James T., D. C.
McConnell, William J., Utah
Meehan, O. Lloyd, D. C.
Meigs, Robert C., Wash.
Meyer, Marcus W., Alaska
Millenbach, Cliff, Wash.
Monson, Melvin A., Alaska
Moore, George C., La.
Moore, Harvey L., Wash.
Morton, William M., Ore.

Nelson, Atley O. Jr., Wash.
Nelson, Philip R., Wash.
Neuhold, John M., Utah
Newcomb, Hugh Ross, Ore.
Newman, H. William, Wash.
Ninnis, Robert A., Wash.

Olson, Paul R., Wash.
Olson, Phillip A., Wash.
Omstead, Duane H., Ont.
Opheim, Boyd R., Mont.

Parkhurst, Z. E., Ore.
Parr, Sam, Ill.
Pautzke, Clarence F., Wash.
Peck, William L., Ore.
Pratt, Virgil S. Idaho
Pritchard, A. L., Ont.
Pycha, Richard L. Jr., Calif.

Rawson, D. S., Sask.
Rayner, John H., Ore.
Reid, Cecil W., Texas
Reimers, Norman, Calif.
Ricker, William E., B. C.
Roach, Lee S., Ohio
Rockwell, Julius Jr., Wash.
Rounsefell, George A., Mass.
Rucker, Robert R., Wash.
Rutherford, Robert M., D. C.

Saltzman, William, Ore.
Schneberger, Edward, Wis.
Schoettler, Robert J., Wash.
Schoning, Robert W., Ore.
Schoonover, Roy E., Kan.
Selden, Charles P., Ore.
Senning, W. C., N. Y.
Seymour, Allyn, Wash.
Shelton, Jack M., Ore.
Shoemaker, Carl D., D. C.
Simpson, James C., Idaho
Skiff, J. Victor, N. Y.
Smith, Spencer H., Miss.
Soumela, Arnie J., D. C.
Southward, Morris, Idaho
Speaker, E. B., Iowa
Sprecher, G. E., Wis.
Stanton, Joseph J., Iowa
Stefanich, Frank A., Mont.
Straty, Richard R., Wash.
Stroud, Richard H., D. C.
Swenson, Hjalmar, Minn.
Swift, Lloyd W., D. C.

Tait, Howard D., Mich.
Tang, Yun-an, Taiwan
Tanner, Howard A., Colo.
Tester, Albert L., Haw.
Thompson, Frederick A., N. M.
Thompson, Richard B., Wash.
Thompson, William H., Okla.
Tunison, A. V., D. C.
Tuttle, Edward M., Ore.

Van Cleve, Richard, Wash.
Van Hyning, Jack M., Ore.
Van Meter, Harry D., W. Va.
Viosca, Percy Jr., La.
Voight, L. P., Wis.

Wade, Gerry, Maine
Wagner, Richard A., Wash.
Walker, Charles R., Mo.
Ward, John M. Wash.
Watkins, H. B., Alta.
Watson, Donald G., Wash.
Way, Seth L., Kan.
Weber, Kingsley G., Wash.
Welander, Arthur D., Wash.
Welsh, Carl R., Colo.
Westerman, Fred A., Mich.
Whitney, Arthur N., Mont.
Witt, Arthur Jr., Mo.
Wood, Edward M., Wash.

OPENING REMARKS OF THE PRESIDENT

FRED A. THOMPSON

In accordance with Section nineteen of the By-laws of the American Fisheries Society the second order of business is "address of the President on a timely subject of his choice." Truly this is a great privilege, but by and large there is little choice without infringing on the duties of the various committees.

I want to take this opportunity to thank all of the committee chairmen and the committee members for their efforts and contributions to the Society.

In perusing the past issues of the Transactions and particularly the remarks of past presidents, it has occurred to me that stress has been laid on keeping the Society in the same pattern. It is not for me to say that this is either good or bad. It may be for me to question whether the Society is moving to keep up with the pace of our present day living. I believe a fact was presented when one of our past presidents made the following statement: "The Society has traditionally been a forum for the presentation of facts and information." This is all well and perhaps as it should be.

But with our facts and information are we keeping up and supplying a need otherwise? Certainly these are basic and should be stressed uppermost. How are we accomplishing this end? We are a group of fisheries workers and interested persons held together in a Society because of our interest or sympathies. Can this mere fact continue or will it take more to attract those not now affiliated?

In 1947 a few far-sighted members practically insisted that divisions be authorized and established to provide for regional meetings where workers could discuss regional problems and still retain membership status in the Society. I believe the division arrangement has met with success and has supplied a need. This is at least evident in part by the fact that two more divisions were formed after the Western Division namely the Northeastern division and the Southern division. All divisions are now thriving and answering a need, not hurting but rather stimulating the parent society.

Programs of various kinds appear to have alternated in the sessions of the Society. A few of you of long membership standing will recall that different meetings have stressed forums, symposia, general papers, biological papers, fish culture papers. In fact, at the Seventy-first session held in St. Louis, President James Brown referred to round table discussion, more or less the type of program you have at this meeting, as "quite radical." Looking away back in the Transactions you will find fish culture stressed with short papers and three times as much discussion. In the early thirties the biologists started to break into print with ideas and facts contrary to general belief. The assembly again changed to a calmer

more sedate gathering. Apparently, either you could not argue with facts as presented by biologists, or the ideas and facts were too ridiculous to discuss. The old fish man was completely snowed under with the strange jargon and complicated graphs and statistics proving that the biologist had the situation well in hand. The early fisheries workers, however, mostly fish culturists, were excellent salesmen: the biologist still hasn't unsold annual fish stocking whether it's needed or not.

There appears to be a change in the type of membership too. The small memberships of the past who perhaps joined to take an active part in the Society realized the value of organization. It seems now that we may have at least three distinct groups. There are those who believe as those of the past and hope to build the Society to something better without personal gain. There are those who have the sole interest in getting the Transactions for reference—the price is the same. There are those who just join in hopes that the affiliation may be of advantage. I'm sure there are many other reasons for taking membership in the Society but regardless of what the reasons might be I want to make this point clear—you all definitely are welcome.

There have been changes of the internal structure of the Society too. The constitution has been changed; the By-laws have been changed. Why? Generally change may be considered as a sign of progress and keeping up with the times; there may have been other reasons. At this meeting the membership will again be called on to express its wishes on a change of the By-laws: to provide for a mail ballot to elect the officers of the Society. This amendment, like those of the past, deserves your personal and serious consideration, it deserves weighing for its benefit to the Society and for its feasibility in respect to the Society administration.

Finally, where are we going? Contrary to the past the Society membership has become topheavy with men technically trained for fisheries work; precise, factual, sincere workers. The tone of the meetings is in harmony with its membership—precise, factual. This in itself has changed the temper of the Society of recent years, but is it a healthy change? There is so much more to the picture of fisheries than just the profession. There has been much criticism of the individual fisheries worker by the administrator because the fisheries seem to be his only interest. That may well apply to the Society too. Permit me to pose a question or two for your thought and consideration. What has the Society done on national issues of both basic and incidental nature and what can or should be done? How far have we gone in cooperation with organized groups of related interests? Is it time for the Society to make its weight felt more in our congress on basic and related fisheries problems? These are some of the things a president begins to wonder about as the business of the Society flows through his hands.

It appears that the future looks bright for the Society but the brilliance of the future will depend on you and me.

APPOINTMENT OF SESSIONAL COMMITTEES

Nominating

George E. Butler, Manitoba, *Chairman*
James H. Cornell, North Carolina
Seth Gordon, California
William M. Lawrence, New York
Stillman Wright, District of Columbia

Resolutions

Milton C. James, Washington, *Chairman*
Jack E. Hemphill, Arizona
Samuel J. Hutchinson, Oregon
Lee S. Roach, Ohio
Fred A. Westerman, Michigan

Auditing

H. H. MacKay, Ontario, *Chairman*
Lester Bagley, Wyoming
A. V. Tunison, District of Columbia

Time and Place

Ralph Hile, Michigan, *Chairman*
I. T. Bode, Missouri
Russell P. Hunter, Connecticut
D. S. Rawson, Saskatchewan
Marion Toole, Texas

Publicity

Fred Peterson, Washington, *Chairman*
Robert C. Holloway, Oregon
Robert C. Meigs, Washington

REPORTS OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

EVERETT B. SPEAKER

Last year, Mr. George Sprecher provided the membership of the Society with a resumé of the activities of the office of Secretary-Treasurer during his five-year tenure. He failed to mention, however, the hectic days that followed his appointment. The war years were undoubtedly responsible for the rather dire straits of our treasury. Costs of printing had soared, and there were several volumes of the Transactions to be published. A never-ending campaign to raise funds was inaugurated, and Mr. Sprecher was able to collect a considerable sum of money from the membership in back dues. Everyone joined hands with the membership committees to recruit new members, and our enrollment increased from some 800 in 1948 to 1,527 in 1953.

The office of the Secretary-Treasurer was moved from Madison, Wisconsin, to Des Moines, Iowa, in October of 1953. The books and files were in perfect order. Through the courtesy of the Wisconsin Conservation Department, and a small financial contribution from the Society, Miss Ann Zweck, former secretary to Mr. Sprecher, came to Des Moines to assist in setting up the office of the Secretary. This was a tremendous help, and a practice well worth following in the future if possible.

Most of the practices established by our former Secretary have been continued, including the bookkeeping system, banking, printing contracts, membership cards, newsletters, *et cetera*.

On March 9, 1954, a meeting of the Executive Committee of the Society was held concurrently with the North American Wildlife Conference in Chicago. The Secretary was ordered to remove the stocks of the New York Title and Mortgage Company Series F-1 Certificate Number 10811, and Title Guarantee and Trust Company Certificates Number 103553 and Number B-71070 from the books and deposit any future monies received from these stocks in the permanent fund of the Society.

Dr. William C. Beckman had reported that the manuscript for the Cumulative Index 1929-1952 to the Transactions was complete, and the Secretary was asked to receive bids for its publication. This was done and the Craft Press, Printers, the low bidder, was awarded the contract to publish 4,000 copies. I was advised by this firm on August 26 that the galley proof would be ready for the Editor the last of September.

Volume 83 of the Transactions is in press and should be ready for distribution to the membership the last of September according to a recent report from our publishers.

MEMBERSHIP REPORT

The membership of the Society has gained over last year and is the highest in the history of the organization. We started the year with 1,527 members and on August 31 there was a total of 1,665, not counting about 67 applications brought to the meeting by the Secretary for approval. On September 1, 151 members were dropped for non-payment of dues, death and other reasons, bringing our membership to 1,514 plus applications received since July 1. Our total membership as of this date, therefore, is 1,581.

Vice Presidents Pritchard and Sprecher, co-chairmen of the hard working Membership Committee, are to be congratulated on their splendid effort to maintain and increase our membership, and thanks are extended to the many others that worked hard on our membership drive.

FINANCIAL REPORT

I am happy to report the financial condition of the Society is excellent. Funds were turned over to me as Treasurer on October 8, 1954. These funds consisted of \$10,043.70 in cash and \$11,716.00 in securities, making a total of \$21,759.70 in the Society's treasury.

On July 1, 1953, there was a balance on hand in the General Fund of \$3,980.12. Receipts for the year ending June 30, 1954, totaled \$8,549.05, giving us a balance of \$12,529.17. Disbursements for the year ending July 1, 1954, were \$7,320.39, giving us a net balance in the General Fund on June 30 of \$5,186.93.

On July 1, 1953, we had a total of \$213.67 in the Permanent Fund. During the course of the year our receipts amounted to \$151.85, or a balance on July 1 of \$365.52. The balance of both funds, therefore, on July 1 was \$5,552.45.

Securities held by the Society as of June 30, 1954, totaled \$10,480.50 in Government Bonds and \$1,488.00 in other securities, or a grand total of \$11,968.50.

On September 1, 1954, there was a total of \$10,473.25 in cash and \$11,968.50 in securities, or a total worth of \$22,441.75. The only outstanding indebtedness at this writing is the cost of publishing Volume 83 of the Transactions and the Cumulative Index of the Transactions. These cost will be in the neighborhood of \$6,000 to \$7,000.

In closing I should like to express my deep appreciation for the tremendous assistance and encouragement from our President, Mr. Fred Thompson, our Vice Presidents, Librarian, Editor, officers of the Society's Divisions, and the entire membership. Without the help of everyone this task would have been much more difficult.

REPORT OF RECEIPTS AND DISBURSEMENTS

July 1, 1953, to June 30, 1954

GENERAL FUND

Balance on hand, July 1	\$ 3,980.12
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Receipts:

Annual Dues

Individual memberships

for the years 1951-52	\$ 90.00	
1952-53	540.00	
1953-54	4,710.57	
1954-55	264.00	
1955-56	5.00	\$ 5,609.57

State memberships

for the years 1952-53	40.00	
1953-54	1,360.00	
1954-55	40.00	1,440.00

Library memberships

for the years 1952-53	43.50	
1953-54	360.00	
1954-55	16.50	420.00

Club memberships

for the years 1953-54	220.20	
1954-55	10.00	230.20

Sale of Transactions and Special Publications	838.75
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Sale of Index	1.50
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Refund on Insurance	9.03
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Plus: Total Receipts	\$ 8,549.05
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Balance, July 1, Plus Total Receipts	\$12,529.17
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Disbursements:

Printing of Transactions	\$ 5,375.37
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Other printing	710.47
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Postage and supplies	206.39
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Indexing Transactions	100.00
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Editing Cumulative Index	130.00
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Reporting services	196.58
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Insurance	107.38
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Fidelity Bond	18.75
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Clerical Services—Ann Zweck (Milwaukee)	70.35
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Clerical Services—Ann Zweck (Des Moines)	52.54
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Dues to Natural Resources Council	50.00
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Petty cash fund deposits for Editor	57.16
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Auditing services	125.00
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Purchase of Transactions	99.00
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Reprints—Craft Press	17.65
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Miscellaneous	3.75
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Less: Total Disbursements	\$ 7,320.39
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Gross Balance, General Fund, June 30, 1954	\$ 5,208.78
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Less: Bank debit memos, etc.	21.85
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Net Balance, General Fund, June 30, 1954	\$ 5,186.93
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PERMANENT FUND

Balance on hand, July 1, 1953 \$ 213.67

Receipts:

Individual Life Memberships	\$ 75.00
Dividend Income	
Consumers Power Co.	61.60
Central Illinois Light Co.	13.20
Mortgage Certificates	
Income Distribution	2.05
Plus: Total Receipts	\$ 151.85

Balance July 1 Plus Total Receipts \$ 365.52

Disbursements:

None

Net Balance, Permanent Fund, June 30, 1954 \$ 365.52

RECAPITULATION

Net Balance, General Fund, June 30	\$ 5,186.93
Net Balance, Permanent Fund, June 30	365.52
Net Balance, Both Funds, June 30, 1954	\$ 5,552.45

SECURITIES HELD JUNE 30, 1954

(1) U. S. Government Savings Bonds

<i>Number</i>	<i>Date Purchased</i>	<i>Mature Value</i>	<i>Value</i>
D682395F	8/29/49	\$ 500.00	\$393.00
M1610061F	8/29/49	1,000.00	786.00
D702345F	12/15/50	500.00	383.50
M1703542F	12/15/50	1,000.00	776.00
M1773328F	10/31/51	1,000.00	754.00
M1773329F	10/31/51	1,000.00	754.00
M1773330F	10/31/51	1,000.00	754.00
M18441J	9/26/52	1,000.00	735.00
M18346J	9/26/52	1,000.00	735.00
M18347J	9/26/52	1,000.00	735.00
M18348J	9/26/52	1,000.00	735.00
M18349J	9/26/52	1,000.00	735.00
M18350J	9/26/52	1,000.00	735.00
M18351J	9/26/52	1,000.00	735.00
M18352J	9/26/52	1,000.00	735.00
		<u>\$14,000.00</u>	<u>\$10,480.50</u>

(2) Consumers Power Company

No. G-6085, 28 shares at $44\frac{1}{4}$ \$ 1,239.00

(3) Central Illinois Light Company

No. B-1752, 6 shares at $41\frac{1}{2}$ 249.00

Total \$11,968.50

PROPOSED BUDGET FOR 1954-1955

GENERAL FUND

Balance on hand, July 1, 1954	\$ 5,186.93
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Estimated Receipts:

Annual dues	\$ 8,000.00
Sale of publications	800.00
Total estimated receipts	8,800.00
Net estimated income	\$13,986.93

Estimated Disbursements:

Printing of Transactions—Vol. 83	\$ 5,400.00
Printing of Transactions—Vol. 84	5,400.00
Printing of Cumulative Index	1,100.00
Other printing	725.00
Clerical services	175.00
Postage and supplies	225.00
Editing	100.00
Reporting services	200.00
Insurance	125.00
Fidelity Bond	18.75
Travel expense	200.00
Dues—Natural Resources Council	50.00
Miscellaneous	250.00
Total estimated disbursements	\$13,968.75
Net Estimated General Fund Balance, June 30, 1955	\$ 18.18

PERMANENT FUND

Balance on hand July 1, 1954	\$ 365.52
Value of securities held July 1, 1954	11,968.50

Estimated Receipts:

Dividends	\$ 75.00
Increment on U. S. Government Bonds	215.00
Net Estimated Permanent Fund Balance, June 30, 1955	\$12,624.02
Net Estimated Balance, Both Funds, June 30, 1955	\$12,642.20

REPORT OF THE LIBRARIAN

HOWARD TANNER

The functions of the Librarian's office during the past year have generally been routine.

A total of 571 volumes of the *TRANSACTIONS*, 72 copies of *Special Publication No. 1*, and 4 copies of the *Index To The Transactions*, 1872-1928, cloth bound, have been sent out from the library, including orders made directly to the Librarian and those paid through the Secretary-Treasurer.

From September 1, 1953 through August 31, 1954 the American Fisheries Society had sold \$1,103.25 worth of material from its library. Receipts in the amount of \$989.25 have been remitted to the secretary-Treasurer with the monthly Librarian's reports of September, 1953 through August, 1954, inclusive. As of August 31, 1954 there were accounts outstanding in the amount of \$114.00.

There was a 78 percent increase in the number of volumes of the *TRANSACTIONS* sold during the year 1953-1954 over the preceding year 1952-1953,—571 volumes compared to 320.

In my report to the meeting of the Executive Committee in March, I suggested that the Librarian's office dispose of 2,129 reprints through the Sport Fishing Institute bulletin listing service. The Committee accepted the suggestion with the modification that the authors be offered up to 50 copies free before the reprints were offered to others. To date, approximately 941 reprints have been mailed out.

A small number of back volumes have been acquired either by exchange or by purchase as authorized by the President.

There has been an increase in the amount of insurance carried on the back volumes stored with the Librarian. Because it is necessary to store the large majority of our back volumes in a non-fireproof, unattended wooden building, the additional insurance seemed advisable.

The value of *TRANSACTIONS* and *INDEXES* stored at the office of the Librarian has now reached \$20,787.50.

I wish at this time to indicate that if the Society wishes, I am willing to serve as your librarian for another year. However, I cannot serve you beyond that time because of increasing pressure of regular duties.

As of August 31, 1954, the number and value of volumes of the *TRANSACTIONS* and other material on hand at the American Fisheries Society Library were as follows:

	Number of Volumes		Value
Index, 1872-1928, Paper Cover	125	(at \$1.00)	\$ 125.00
Index, 1872-1928, Cloth Bound	437	(at \$1.50)	655.50
Special Publication No. 1	966	(at \$.25)	241.50
Volumes 1882 through 1929	393	(at \$1.00)	393.00
Volumes 1930 through 1952	4305	(at \$4.50)	19,372.50
Total	6226		\$20,787.50

REPORT OF CHAIRMAN OF THE SOUTHERN DIVISION

LAWRENCE F. MILLER

The Southern Division of the Society held its second annual meeting October 11-14, 1953 at Chattanooga, Tennessee. The meeting was well attended and went off in good style. There were 50 members and 22 non-members in attendance. Since the meeting a number of the non-members have joined the parent society. All of the 13 southeastern states were represented as well as Ohio, Washington, D. C. and Cuba. In addition to technical fisheries papers the program included a demonstration of Tennessee's fish shocker, as well as panel discussions regarding the Mississippi threadfin shad, white bass and walleye.

The membership of the division stood at 229 in November 1953 and as of May 1954 stood at 231. The funds on hand as of September 1, 1954 amounted to \$56.99.

REPORT OF CHAIRMAN OF THE WESTERN DIVISION

A. F. C. GREENE

The Western Division met in conjunction with the Western Association of State Game and Fish Commissioners at Las Vegas, Nevada, on May 3, 4 and 5, with approximately 70 fisheries workers in attendance. All the 11 Western States were represented. The meeting was conducted by Chairman A. F. C. Greene of the Wyoming Game and Fish Department and the program was under the chairmanship of Dr. H. J. Rayner of the Oregon Game Commission.

The program was conducted in such a manner that panel discussions could be had on several broad subjects after individual papers were given in abstract form. Panel subjects included: "The Use of Fish Toxicants in Fishery Management", "Data and Results Pertaining to Certain Fish Grading Operations", "Farm Pond Development and Management", "Comparative Costs of Trout Fry and Fingerling Plantings in High Mountain Lakes", and "Survival Studies".

Dr. Paul R. Needham, University of California; Clarence F. Pautzke, Washington Department of Game; Dr. H. J. Rayner, Oregon Game Commission; and A. F. C. Greene, Wyoming Game and Fish Commission, took part in a panel discussion "How Far Can We Go with Artificial Stocking in Fisheries Management" as part of the program of the Western Association of State Game and Fish Commissioners. Marion M. Madsen, Utah Fish and Game Commission, acted as discussion leader.

The Division was privileged to have Fred M. Thompson, President of the parent society in attendance and a breakfast was given in his honor on the morning of May 5.

Resolutions passed by the Western Division included: That the Fish and Wildlife Service be requested, through the Dingell-Johnson administration, to prepare abstracts of published articles pertinent to sport fisheries research and management which would be disseminated among the various member States and Provinces; that legislation be sought by all Western States that will assure that fish production and management be definitely recognized as a beneficial use of water in all water-use projects and that this resolution be submitted to all appropriate agencies and authorities; that the executive committee of the Western Division meet with the parent society to discuss the matter of the most desirable means of presenting papers, their consideration by the editorial board and the consideration of the hiring of a paid editor; and, that the Nevada Fish and Game Commission and other responsible organizations be advised of our appreciation and gratitude for a most successful convention in Las Vegas.

There was much interesting discussion during the business session concerning such matters as enlarging the membership, the type of meetings that could be anticipated in the future and the presentation and printing of papers.

The new officers installed during the business session on the last day were: Chairman, Alex J. Calhoun of the California Department of Fish and Game; Vice-Chairman, Walter M. Allen of the Montana Fish and Game Department; and Secretary-Treasurer, Lewis R. Garlick of the U. S. Fish and Wildlife Service, Portland, Oregon.

REPORTS OF STANDING COMMITTEES

COMMITTEE ON INTERNATIONAL RELATIONS

LAUREN R. DONALDSON

The reports of the American Fisheries Society Committees on International Relations for the years 1951 and 1953 developed at length the difficulties inherent in their efforts to summarize the international relations of a field as vast and ramified as fisheries. We should like to add our voice also to their statement that "lately the task has become more and more difficult and in the not-too-distant future will be *almost* impossible."

We should also like to reiterate the plea that the executive committee "review the duties and responsibilities with a view toward determining whether more specific directions might be laid down" so that the committee could report with thoroughness on specific phases of international relations rather than make attempts at "virtually a summary of those international negotiations with which the members may have had immediate contact."

Lacking a directive from the executive committee that would more specifically define our tasks, we have attempted again to pool our several experiences and report on the international aspects of fisheries that have come to our attention.

INTERNATIONAL FISHERY AGREEMENTS

The International Commission for the Northwest Atlantic Fisheries.—The Northwest Atlantic Commission held its fourth annual meeting in Halifax in June 1954. The most important business before it was a review of the research conducted under the comprehensive research program and a study of the effects of the haddock regulation in Subarea 5, the Gulf of Maine and George's Bank. The past year has seen steady progress in the coordination and integration of the research efforts of the member governments and important contributions to scientific knowledge in the field of hydrography and in the study of redfish and haddock. Experience gained during the first year of operation under the comprehensive research program has shown the need for simplification of the plans established to insure coordination. Although the evidence is not yet sufficient to permit definite conclusions, after a little more than a year of operation, the haddock regulation in Subarea 5 appears to be having the effect predicted. The number of small haddock in the catch has decreased significantly and the larger haddock and total catch have increased. It is estimated that the regulation is earning the haddock fishery an additional one million dollars a year.

The International North Pacific Fisheries Commission.—The North

Pacific Commission, newest international fishery commission of which Canada and the United States are members, held its first meeting in February 1954 in Washington. The Commission was established by the Convention entered into by Canada, Japan, and the United States in May 1952. The first meeting was organizational. Steward Bates, Deputy Minister of Fisheries of Canada, was elected Chairman for a two-year period; Iwao Fujita of Japan was elected Vice Chairman; and Edward Allen of the United States was elected Secretary. The Commission established two standing committees, one on finance and administration and one on research. A budget of \$33,000 was agreed upon for the first year, the University of British Columbia at Vancouver was chosen as the site of the Commission's headquarters, and Milton C. James was selected as Executive Director *pro tem*. Several important research problems were discussed by the Commission, and its Committee on Research was given the task of formulating a research program which would enable the Commission to solve these problems. This Committee met in May 1954 in Tokyo and will meet again in Vancouver in October, immediately prior to the annual meeting of the Commission.

The Inter-American Tropical Tuna Commission.—In spite of a relatively small budget, the Inter-American Tropical Tuna Commission has made impressive strides toward its objectives. A large amount of data has been gathered and partially analyzed. Though the evidence is not conclusive, it indicates the possibility that some of the tuna stocks are now or may be in the near future fished more intensively than desirable if maximum yield is to be sustained. The Commission has made progress in its study of bait fishes, and of special interest is the experimental planting of bait fish in the Gulf of Nicoya, once an important source of these species. The government of Panama adhered to the Convention in 1953 and became a member of the Commission.

The International Pacific Halibut Commission.—The investigations of the Pacific Halibut Commission have continued during the past year with added significance following the entry into force in 1953 of the latest agreement between Canada and the United States. The Commission's regulatory powers have broadened to permit more than one fishing season in an area each year and thus enable the industry to fish stocks that have not been adequately utilized for many years. As a result of these changes in the regulations the total catch in 1954 reached 69½ million pounds which exceeds the 68¾ million pounds caught in 1915 when virgin stocks were being fished along various parts of the coast. The 1954 catch is 25 million pounds greater than that of the year immediately preceding regulation—1931—thus again pointing up the great value of sound conservation measures when applied to an international resource.

The International Pacific Salmon Fisheries Commission.—Steadily increasing runs of sockeye salmon in the Fraser River indicate the success of the Pacific Salmon Commission. The 1953 catch was 193,067 cases greater than its parent run, four years earlier, continuing a trend which first became apparent in 1949. In the meantime, the Commission has been

devoting much effort to a study of the factors which affect spawning success as well as to a study of the effects of economic development of the Fraser River Basin. The Kenney Dam on the Nechako River was closed in October 1952, and the Commission has been investigating the effects of the reduced flow in this river upon the spawning runs. During the 1953 migrations, sockeye successfully passed through the portions of the river which were reduced in flow. They were greatly aided, however, by a wet season and cool climatic conditions. The Commission also prepared recommendations in connection with the construction of a dam on Seton Creek and the disposal of wastes from an oil refinery on the Thompson River. Studies of the rehabilitation of barren areas continue.

The International Whaling Commission.—The International Whaling Commission held its sixth annual meeting in Tokyo July 19–23, 1954. A number of amendments were made to the regulations controlling pelagic whaling in the Antarctic, the most important of these providing for a delay in the opening of the season until January 7 for fin whales and January 21 for blue whales. (The catch is now limited to 15,500 blue-whale units each year—a blue-whale unit being calculated on the basis that one blue whale equals two fin whales, or two and one-half humpback whales, or six sei whales.) The Commission has been presented with evidence indicating that the blue whale stocks have been seriously over-exploited and that these valuable animals may well disappear from the fishery in a few years. The delay in the opening of the season provides considerable protection to the blue whales, since they arrive in the Antarctic early and leave well before the approach of the Antarctic winter. The Commission's scientists have warned, however, that further protection will be necessary for fin whales as well as blues, and that a drastic reduction in the seasonal catch limit may soon become imperative.

Pelagic whaling in the Antarctic was stopped this year at midnight on March 18, by which time 15,439 blue-whale units had been taken. Seventeen factory ships operated during the 1953–54 season with 206 whale catchers and their total output of whale oil amounted to 2,100,879 barrels. Land stations produced another 184,647 barrels, making a grand total of 2,285,526 barrels.

The Commission will hold its next meeting in Moscow in July 1955.

Great Lakes Fisheries Convention.—Representatives of the United States and Canada signed a Convention on Great Lakes Fisheries on September 10, 1954 in Washington.

The Acting Secretary of State, Walter Bedell Smith, and the Special Assistant for Fisheries to the Under Secretary of State, William C. Herrington, signed on behalf of the United States. The Canadian Ambassador in Washington, Arnold Heeney, and the Canadian Deputy Minister of Fisheries, Stewart Bates, signed on behalf of Canada.

The Convention provides for joint action by the United States and Canada in the field of fishery research and elimination of the predatory sea lamprey in the Great Lakes. To carry out this task, both governments agree to establish a Great Lakes Fishery Commission of three appointees from each country.

The duties of the Commission include the formulation of research programs regarding the Great Lakes fisheries and the formulation and implementation of comprehensive programs for the destruction of the predatory sea lamprey, which has been playing havoc with some of these fisheries, especially the whitefish and lake trout. The Commission may recommend to the governments, on the basis of research finding, measures to make possible the maximum sustained yield of Great Lakes fisheries. The Commission will have, however, no regulatory powers. In the performance of its functions the Commission will, wherever feasible, make use of the existing state, provincial and federal agencies in each country.

The Convention, with an initial duration of ten years, will become effective upon ratification by both countries.

TECHNICAL AID PROGRAMS

UNITED STATES FOREIGN AID

Foreign Operations Administration.—Technical aid to underdeveloped friendly nations, which was formerly administered by several agencies whose relations to each other changed from time to time, is now the function of the Foreign Operations Administration, Harold E. Stassen, Director. The Administration was established by President Eisenhower's Reorganization Plan No. 7, Section 1, dated June 1, 1953.

A few fishery projects now in force were initiated by FOA, or by one of its predecessors, and have been carried on without the active cooperation of technical agencies of the government. These are the projects in Thailand, Indo-China, Formosa, and Turkey. In each case, emphasis is being placed on development of the offshore fisheries, although attention is given to integrated growth of the fishing industry in general. There are no United States fishery technicians resident in Formosa and Turkey presently, but it is expected that these will be provided soon. Milton J. Lobell is the technician in Thailand, and Harry C. Timmes in Indo-China.

Fish and Wildlife Service.—A number of projects are administered by FOA in close cooperation with the Fish and Wildlife Service. The Service determines the technical feasibility of proposals, recruits personnel, and provides technical servicing and some administrative servicing of field parties, with funds transferred by FOA. On August 1, 1954, projects of this kind were being maintained in Mexico, Ecuador, Peru, El Salvador, Liberia, Iran, Pakistan, India, and Indonesia. A project in Egypt was terminated in June; and a preliminary survey was made of trout waters in Panama early in the year. A brief study of the inland waters of Bolivia was planned for August.

Parallel with the demand for fishery development and industrialization has come a greater realization in many countries of the need for training their own people. As a result, students are being sent to the United States in increasing numbers for training in fishery science and technology.

During the past fiscal year, nine countries sent 33 participants for training in 11 different technical branches of the fisheries. Seventeen students of various branches of fishery technology came from Cuba, India,

Indonesia, Iran, Pakistan, and Thailand. Seven students of fishery biology (marine and fresh-water) came from China (Formosa), India and Pakistan, and four in fish culture came from China, Iraq, and Thailand. Indonesia and Thailand sent four students of fishery administration and statistics, and one came from South Africa for studies in the management of seal resources. Training periods varied from a few months to a year and usually included university studies and visits to fishing industry centers.

CANADIAN CONTRIBUTIONS UNDER THE COLOMBO PLAN

Canada has contributed substantially to the Colombo Plan in fisheries during 1954. Explorations for new fishing "banks" off the shores of Ceylon have been continued and surveys of the former producing areas have been extended. Different methods of catching fish are being tested while improvements in small fishing craft, gear and gear-handling devices are the objects of experiments presently in progress under the supervision of Canadian scientists and experts.

In the technological field methods of preserving the catches, methods of processing and handling, and facilities for transporting fishery products have been studied. Plans and specifications for a complete fish plant including the handling of fresh fish, the production of ice, the freezing and storing of fish and the reduction of waste products into meal and oil have been prepared and the contracts for erection have been awarded. The plant is designed to meet local needs and to demonstrate the efficacy of the newer preservational techniques.

In order that the projects initiated with outside help may continue, a biological and technological laboratory is being set up through Canadian effort. Singhalese scientists and technicians are being trained to carry on the programs designed to establish the fishing industry in Ceylon on the highest possible level of productivity on a practical basis.

NORWEGIAN FOUNDATION FOR ASSISTANCE TO UNDERDEVELOPED COUNTRIES

The technical assistance project in India is popularly known as the India Aid Foundation. Upon his return from India in May, Professor H. U. Sverdrup, Board Chairman of the Foundation, was quoted as saying that he was very optimistic about the future prospects for the Norwegian venture. "My stay in Travancore-Cochin and in New Delhi," he said, "convinced me that the Norwegian specialists and the Indian state and federal authorities are working together in a spirit of mutual trust."

The India Aid Foundation was established by the Norwegian Parliament on June 25, 1952. The program is financed by a grant of Kr. 4 million from the Norwegian Parliament and an additional Kr. 4 million by public subscription in Norway.

The program is centered in the State of Travancore-Cochin and has as its immediate objective the repair and modernization of fishing boats,

introduction of new types of fishing equipment, fish processing and curing methods, building ice plants, developing transportation methods and facilities, etc.

The program is a tripartite one between India, Norway, and the United Nations. India provides the supply of local building materials, a headquarters site, and local Indian personnel. The United Nations furnishes technical assistance and Norway supplies the necessary machinery, equipment and technical personnel. Scholarships are also granted to Indians to receive specialized training in Norway.

FOOD AND AGRICULTURE ORGANIZATION

The Food and Agriculture Organization of the United Nations through its regional fisheries councils seeks to promote and coordinate technical research and development of educational programs with the aim of increasing fisheries production and improving efficiency in its utilization. During 1953-54 the fisheries councils have been very active:

Indo-Pacific Fisheries Council.—The Indo-Pacific Fisheries Council held its fifth meeting in Bangkok, Thailand, January 22 to February 5, 1954. Delegates and advisers attended from thirteen of the sixteen member countries, namely: Australia, Burma, France, India, Indonesia, Japan, Korea, Netherlands, Pakistan, Thailand, the United Kingdom, the United States and Viet-Nam. The work of the Council's technical committees was reviewed—Technical Committee I reported advances in the collection of information on pollution of natural waters, on Hilsa and Chanos investigations, neriticpelagic, oceanic and miscellaneous fisheries, while the collection of information on indigenous methods of gear preservation was the main feature of Technical Committee II's report. Emphasizing the role of plankton in fisheries development, a Symposium on Plankton was held with UNESCO as co-sponsor. A Symposium on Marketing was also arranged.

One important accomplishment of the meeting was simplification of the Council's sub-committees and working groups and a shift of emphasis from somewhat academic studies to those which will contribute directly to the increasing of food supplies in the Indo-Pacific area. The Council continues to play an important role in bringing together the administrators and scientists of its member governments and providing a medium for exchange of information and concerted attack upon common problems.

At the invitation of the Japanese Government, the sixth meeting of the Council will be held in Tokyo in October 1955.

General Fisheries Council for the Mediterranean.—The General Fisheries Council of the Mediterranean held its inaugural meeting in Rhodes, Greece, in July 1952 and eleven governments have now ratified the Agreement. The second meeting was held in Rome, October 26-30, 1953, and attended by delegates from France, Greece, Israel, Italy, Spain and Yugoslavia and observers from six governments and international organizations. In addition to the Technical Committees on Exploration, Produc-

tion and Utilization, two further committees on Statistics and Inland Waters were set up. The Proceedings and Technical Papers presented at the meeting have now been published.

The next meeting is to be held in the Principality of Monaco on October 14-19, 1954.

Latin American Fisheries Council.—An agreement for the establishment of this Council was formulated at Lima, Peru, in September 1951 and approved by the Sixth Session of the FAO Conference held the same year. Ratification of the Agreement by five member governments is required before an inaugural meeting can be held and, in view of the urgent need for fisheries development in most Latin American countries, efforts are being made to bring the Agreement into force as soon as possible.

The FAO Interim Committee on Fish Handling and Processing.—The FAO Interim Committee on Fish Handling and Processing was formed in 1950, mainly to serve the northwest European region, but corresponding with contacts in all parts of the world. Four working groups deal with: Fisheries Products for Tropical Consumption, Prepackaged Fisheries Products, Chilling of Fish and Freezing of Fish in Bulk.

The Fisheries Division also maintains contact with the following international and governmental organizations in the Fisheries field, attending their meetings, contributing papers and exchanging publications: International Commission for the Northwest Atlantic Fisheries, International Commission for the Scientific Exploration of the Mediterranean Sea, International Council for the Exploration of the Sea, International Institute of Refrigeration, Caribbean Commission, International North Pacific Fisheries Commission, International Whaling Commission, South Pacific Commission, Comité International Permanent de la Conserve, Gulf and Caribbean Fisheries Institute.

INTERNATIONAL MEETINGS

International Council for the Exploration of the Sea.—The International Council for the Exploration of the Sea met in Copenhagen from September 27 to October 6, 1953. The United States observer was Dr. Herbert W. Graham, Chief, North Atlantic Fishery Investigations, Fish and Wildlife Service.

An announcement of great moment was that the International Fishing Convention of 1946 had been ratified by all signatory governments and a permanent Commission had been established. This action brings offshore fishing in a large area of the eastern Atlantic Ocean under international control for the first time. The establishment of this Commission is one of the great achievements of the International Council for the Exploration of the Sea.

A number of papers dealing with the cod fisheries were read before the conference, and an important discussion was held dealing with the selectivity of nets. The Council will hold its next meeting in Paris in October 1955.

Great Lakes Fishery Committee.—At the annual meeting of the Great Lakes Lake Trout and Sea Lamprey Committee held in Chicago on December 8, 1953, it was decided that the name be changed to the Great Lakes Fishery Committee. The Federal-Provincial Committee of Canada was granted representation on the Great Lakes Committee. Membership is therefore composed of representatives of the following agencies: Federal Government of Canada, Province of Ontario, Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York and the United States Fish and Wildlife Service. Annual meetings have been held since 1946 and have resulted in a better understanding of Great Lakes fishery problems and in coordinated research programs in which all agencies cooperate.

Gulf and Caribbean Fisheries Institute.—The sixth meeting of the Institute was held at Miami Beach, November 16–20, 1953, with about 250 persons in attendance. The industry session was concerned with handling of shrimp and quality control in a fish plant; the economic session with financing of fishing vessels; the biology session with accomplishments of fishery biology; and the technical session with quality and packaging of shrimp. The next meeting is scheduled for Havana, November 15–19, 1954.

International Fishing Boat Congress.—The Congress, sponsored by the Food and Agriculture Organization of the United Nations, was held at Miami Beach, November 16–20, 1953. An earlier session of the same meeting was held in Paris in the period October 12–16. In addition to European and Latin American representatives, a number of persons in United States industry and government attended the Miami Beach meetings. The purpose of the Congress was to bring together some of the world's leading marine architects, engineers, and builders of fishing vessels for an exchange of information and ideas. Numerous technical papers, on subjects ranging from the design of fishing boats to machinery for freezing fish at sea were presented and discussed at open sessions. It is generally believed that the Congress was successful in accomplishing its aims. The proceedings will soon be issued in book form.

International Limnological Congress.—The Twelfth Congress was held in Cambridge, England, August 12–25, 1953, with nearly 300 persons from 39 countries attending. Extensive tours were arranged to places of special interest in England, Scotland, and Ireland. The Congress is assembled every third year.

RADIOACTIVE ASH CONTAMINATION FROM WEAPONS TESTS

A new type of international fisheries relations problem developed during the year. Following the weapons test at Bikini Atoll, Marshall Islands, on March 1, 1954, radioactive ash fell upon the Japanese fishing trawler, *Fukuryu Maru* (Fortunate Dragon). This radioactive ash caused injury to the members of the crew and contaminated the vessel, the fishing gear and the fish dragged over the decks. The Japanese and American press,

subsequently, were filled with stories of radiation contamination of fish coming from the central and western Pacific. These stories caused considerable alarm in both countries in the fish industry and the consuming public.

The United States Atomic Energy Commission immediately initiated studies designed to measure the extent of contamination and in collaboration with the Food and Drug Administration established inspection service for tuna.

The Sixteenth Semiannual Report of the Atomic Energy Commission reviews the problems of radiation contamination following the recent tests, pages 51 through 53. The entire problem of radiological contamination is of such great present and future interest that pertinent portions of the report are included here.

RADIATION EXPOSURES IN RECENT WEAPONS TESTS

Prior to the recent weapons tests a danger zone was established surrounding the proving grounds; within this area a hazard from radiation might exist to shipping or aviation. Appropriate notices on the boundaries and the establishment of the danger zone were carried in marine and aviation navigational manuals. Before each shot of the series, a careful survey was made of the winds at all elevations up to many thousands of feet, and survey aircraft searched the area for shipping. The purpose was to take every precaution against radiation exposure of inhabitants of the area, the task-force personnel, and crew or passengers of vessels or aircraft.

During the tests, radiological monitoring teams were set up and the monitoring network of stations as usual was in operation to collect and measure fall-out—radioactive particles from the explosion descending to the lower atmosphere, the sea, or the earth. Measurements were made of airborne, ground, and water activity. The only fall-out of consequence was that which followed the first detonation of March 1, when a shift of the winds occurring after the detonation carried radioactive particles toward the islands of Rongelap, Rongerik and Utirik. Thirty-one American test personnel, and 236 Marshallese were exposed to radiation. A Japanese fishing trawler, the *Fukuryu Maru* (Fortunate Dragon) was also in the path of fall-out.

Japanese Vessel Exposed to Fall-out

The Japanese fishing vessel, *Fukuryu Maru*, was reported by its captain as being located at approximately 50 miles northwest of Rongelap Island ($11^{\circ} 53\frac{3}{4}'$ North latitude and $166^{\circ} 35\frac{1}{4}'$ East longitude) at the time of fall-out in that area. Following return of the ship to Japan on March 14, a report by the Japanese authorities stated the crew members were ill and showed skin burns from radiation. Japanese physicians gave the crew members medical treatment. Medical assistance was offered the Japanese by the United States through the American Embassy at Tokyo. The Japanese have not yet called for such assistance. However, they did request United States aid in making chemical analyses of some urine samples. These were performed at Commission laboratories. The injured men are reported by the Japanese physicians to be improving satisfactorily.

It is regretted that the crewmen of the *Fukuryu Maru* were injured as the result of being exposed to radiation from the first detonation of the recently concluded series. The welfare of the patients will continue to be of interest to the United States, and the negotiations for settlement of this incident are being handled through the Department of State and the American Embassy in Tokyo. In this connection Ambassador Allison informed the Japanese Government that

the United States would pay just compensation and also would reimburse the injured fishermen for reasonable expenses for current medical care and family relief, including wages.

Reports on Contaminated Tuna Fish

Fish aboard the *Fukuryu Maru* were reported by the Japanese press to be grossly contaminated with radioactive materials. Quantitative data on the degree of contamination are few. It appears probable that observed contamination consisted largely of radioactive materials on the exterior surfaces of the fish from contact with fall-out material on the ship. United States representatives in Japan were not afforded an opportunity to verify the fact or the degree of radioactivity reported for this or later for other cargoes.

Subsequent to the return of the *Fukuryu Maru*, a number of other Japanese fishing vessels and their cargo were reported to involve sufficient radioactivity to require destruction of the fish. In one instance a single specimen fish was made available for study. Analysis of this specimen at an AEC laboratory showed the radioactivity of the edible portions to be well within acceptable limits for food and water for continuous use by humans.

The amount of activity in Bikini and Eniwetok lagoons would make it unwise to eat fish from these areas, at least for the present, without having them monitored prior to human consumption. Information presently available indicates that the fish in the lagoons of Rongelap, Rongerik and Utirik are suitable for consumption. The activity in the lagoons other than Bikini and Eniwetok and in the open sea is so small that no deleterious effects may be expected to the fish themselves nor will the edibility of the fish be impaired.

Informed scientific opinion, borne out by recent continuous monitoring by the Federal Food and Drug Administration of tuna fish coming to the west coast from the Pacific fishing grounds, and further supported by several years' results of AEC marine biological studies, provides no basis for alarm as to the consumption of tuna caught in the Pacific.

COMMITTEE ON NATIONAL-STATE RELATIONS

MICHAEL HUDOBA

The most important item of legislation in the fisheries programs on a national basis of cooperation between the states and federal government is the Dingell-Johnson federal aid in fish restoration. It not only has expanded the opportunities for fishery programs, but has opened the way to increase opportunities for members of the American Fisheries Society.

STATUS OF THE DINGELL-JOHNSON FEDERAL AID IN FISH RESTORATION PROGRAM

Information received from the U. S. Fish and Wildlife Service indicates that the past year set new records for both financing and on-the-ground accomplishments under the well-known Dingell-Johnson program. The amount available for apportionment to the States made a spectacular jump to \$4,556,615, an amount equal to 75 percent of the total collections for the previous two years. After deductions by the Fish and Wildlife Service for administrative overhead and projects underway in the Terri-

tories, \$4,419,916 were available to the States. To gain a better perspective of what the Dingell-Johnson program has meant in terms of bolstering the financial status of the respective State fishery programs, it is necessary only to realize that \$9 $\frac{3}{4}$ millions were made available to the States in the first three years of program operation. In many states, Dingell-Johnson funds are virtually all that is available for sport fish conservation outside of that which is tied up in the operation of fish hatcheries.

The States and Territories began operation on 301 fish restoration projects on which a total of \$3,929,774 were obligated. One hundred thirty-six projects utilizing some 52 percent of available funds, were designed to add to the knowledge required for intelligent management of the States' fisheries resources. General surveys, designed to provide a biological inventory of the States' fisheries resources, were being carried out in 23 States in a total of 37 projects. Greater attention was paid in the past year to the investigation of problems restricted to specific water areas or involving a particular species or group of species of fishes. The 56 projects with this more limited scope, designed to solve a specific problem, were underway in 27 States. Creel census, or other harvest studies and investigations of the dynamics of fish populations, were the center of attention in 13 projects, while 19 projects were being carried out to study some phase of the biology of marine or anadromous fishes. In this connection, it would be well to call attention to the cooperative striped bass program which is now being carried out on the Atlantic Coast. Eleven of the coastal States are carrying out some phase of an over-all study of this famous marine sport fish throughout its range on the Atlantic Coast. The study is being financed with Dingell-Johnson funds in 6 States, and the cost of coordinating activities is being borne by the Fish and Wildlife Service. Dr. Edward Raney, well-known Cornell University expert on the striped bass, is serving as project coordinator.

Other research activities, which consist of investigations in various problems of fish culture, including control and prevention of diseases, general ecological problems, distribution of fishes, and a variety of other subjects, make up the balance of the investigational projects.

Of particular interest are those projects which result in the immediate creation of expanded fishing opportunities. In this category are such activities as the construction of dams, with the resultant impoundment of public fishing waters, the rehabilitation of fishing waters through the poisoning and restocking technique, and the enhancement of stream conditions through watershed improvements. If brought together in one place, the 29 lakes and ponds built by 15 States on Dingell-Johnson projects last year would create a body of water with a total area in excess of 2,500 acres. Notable among the rehabilitation projects was North Dakota's treatment of the James River Basin above the Jamestown dam. The 6,920 acres of water area in this 1,245 square mile watershed were treated with toxicant to eliminate trashfish prior to the closure of the recently completed Jamestown Dam, which was built by the Bureau of Reclamation. In all, 38 lakes, with a total area of 13,800 acres, were treated with rotenone or

other chemical during the year. Altogether, 76 projects of this general type, obligating 35 percent of total available funds, were approved last year.

Twelve States purchased 2,945 acres of land or water for use in various ways in the States' fisheries programs. Most of the land purchases were made in order to provide sites for the construction of dams and fishing lakes, although the acquisition of access areas, which will insure public access to fishing waters, was also a popular and meritorious activity.

Forty-five States had projects which provided for financial assistance in the direction of their Federal Aid in Fish Restoration programs. The amount of funds allocated for this administrative function was 6 percent of total project obligations.

The outlook for the current year is as favorable as it was last year. The Bureau of Internal Revenue has reported the collection of \$4,625,337 which became available for obligation by the States on July 1, 1954. Thus, there is the assurance that the States will have substantial funds for a continuation of these restorative measures which are doing so much to add to our store of fishing opportunities.

There are several items of federal legislation enacted into law which will open up far reaching opportunities for fishery programs. These are in the field of watershed restoration.

The first is provision in the revised tax laws that will allow a landowner to deduct the money he spends for soil, water and land erosion prevention conservation projects for income tax purposes. This will lead to a number of private farm pond, retention reservoirs, and land restoration projects to reduce stream siltation, with a related need for management of these water areas for fishery uses. Fishery workers would be remiss if they overlooked the opportunities that will become available in this field.

The second is passage of the Hope-Aiken watershed restoration bill that puts into law the pilot watershed program started two years ago. One of the basic provisions of this program that will be carried on at local watershed levels in cooperation with private, watershed associations, state and federal efforts is the construction of headwater retention reservoirs up to 5,000 acre foot capacity.

The fish management techniques for this new type of retention reservoir will in a number of cases present challenges, and yet open a large new field of opportunity to expand fishery programs. Nor, may we overlook the resultant benefit to more stable and better stream flow resulting from such watershed restoration projects completed and their resulting benefits to fish habitat.

These two newly enacted laws will have a far-reaching potential of opportunity to expand fishery programs.

There were no other laws of direct interest to fishery in this Congress. The trout labelling bill was vetoed by the President. It would have given the private trout hatcheries an improved economic position.

The special grazing on national forests bill was killed during the final pre-adjourment hours of Congress after it had passed the Senate. The provisions of this measure would have impaired fish and wildlife and

recreational programs on the 180,000,000 acres of national forests. It would have required the Secretary of Agriculture to encourage building of fences for grazing uses by livestock permittees, with the resultant problems of unrestricted uses. The defeat of this measure in which your Chairman had spent considerable effort will serve to keep the forest areas continuingly available.

There has been a setback with the newly announced policy under Public Law 732, known as the Co-ordination Act, which restricts land acquisition on federal reservoir policies. The Corps of Army Engineers and Interior Department have jointly agreed the potentials that preliminary studies under the Co-ordination Act suggest for fish and wildlife values in such projects. An effort will be made to clarify this issue and to strengthen the law in the next Congress.

As a member of the Secretary of Interior's Advisory Committee on Conservation, your Chairman took issue with the Secretary on the failure to provide for salmon runs on the American River, tributary to the Sacramento in California. This issue was favorably resolved.

A report was submitted by Alex Calhoun, Committee member from California, on the California situation which follows:

"In general, our experience in California indicates a steady improvement in the field of agency interrelationships. The various organizations having to do with water problems are being gradually educated to appreciate the importance of giving adequate consideration to the fisheries involved. Continued progress was made along that line, at least in California, during the past year. An outstanding example was the way in which the Bureau of Reclamation finally agreed, after considerable persuasion and a great deal of "educational activity" on our part, to take adequate protective measures for the important king salmon run on the American River, tributary to the Sacramento. They are building a salmon hatchery which will cost nearly \$1,000,000 along the lines recommended by us, and they will provide us with the funds to operate this hatchery when completed. It will have a capacity of about 40,000,000 to 50,000,000 eggs. This example is fairly typical of half a dozen projects throughout the state, typical, that is, in the way things are being worked out satisfactorily for the fish so far as we are concerned.

"Another thing which I think is very important is the outstanding manner in which the Federal Dingell-Johnson staff in our region is doing everything in its power to work with the states and to facilitate their programs at the same time that they exercise the proper sort of Federal control. We have only the highest praise for the manner in which these people have worked with us, and although I have not had an opportunity to poll our neighbor states on this point I am reasonably sure that most of them would agree."

C. J. D. Brown, Committee Member from Montana, suggests the need for a Fisheries Review to cover all current literature—similar to the Wildlife Review. He believes this is a matter for either the D-J group or someone else in the Fish and Wildlife Service. Very few of the states have access to the library facilities necessary for this or would feel financially able to do a thorough job just for their individual benefit.

Dr. Brown feels that a properly prepared review would certainly be of great use to all state and federal workers and would save hundreds of hours of duplicate library work in some instances of duplicate research.

In summary of conclusions, there seems to be a continuing progress toward improvement of cooperation enhanced by the Dingell-Johnson program between state and federal fishery agencies. But, the study being conducted by the Federal Commission on Inter-governmental Relations, through a committee headed by William Rosecrans, will deal with federal aid programs including the D-J program. This committee should be made aware of the values from the D-J program and needs to improve, for its recommendations will have a direct influence in future top level administrative and legislative proposals.

There are some underlying potential problems that will affect the D-J program in the report of the survey team which studied Fish and Wildlife Service operations designed to improve administration of that Service.

The Co-ordination Act needs strengthening to assure that the fishery values to be gained from federal reservoir construction and their management by the state agencies can be adequately realized.

The watershed conservation-restoration programs offer a large area of opportunity for new and expanded fishery work and development of new fish habitat areas. This program under the new law should be fully explored so that state fishery programs will be in a position to participate fully.

The watershed conservation programs not only have a direct benefit to water and streams, but their restoration also affords fishery technicians and scientists to cooperate in broader resource conservation efforts.

There is a continuing need for liaison between the technician and the layman in order that understanding may be developed further so that the needed support for stepping up fishery programs may be realized.

EDITORIAL BOARD

KIYOSHI G. FUKANO

I regret that it was impossible to have Volume 83 of the *TRANSACTIONS* in the mail in advance of this meeting. Two unavoidable situations account for the delay. First, some time was lost while a new printing contract was being negotiated. Second, and more damaging to our schedule, dealings with certain contributors to the symposium on fish diseases were so long and tedious that the last copy did not go to the printer until well into the summer. A symposium, I should explain, places an editor in a difficult situation. Since all of the papers must be included if the symposium is to have its greatest value, publication is inevitably delayed if excessive time is needed to place even one article in condition for printing. In a volume composed of independent contributions from a variety of sources a particular paper that causes difficulty simply can be carried over to another issue.

The symposium held at Milwaukee last year long will stand as a

valuable contribution to fishery literature. We may anticipate that future Program Committees will arrange symposia on other subjects of current interest. I would suggest that to avoid delays of publication similar to the one that took place this year all future symposia be planned in close cooperation with the Editorial Board. Contributors should be advised fully as to the editorial policies of the *TRANSACTIONS* and should prepare manuscripts for examination by the Editor either in advance of or immediately following the meeting.

I do not wish to imply that but for difficulties with the symposium the *TRANSACTIONS* would have appeared shortly after our last annual meeting. Hard experience has proven that a properly handled volume cannot be issued in less than 10 or 11 months. This time span held even for volumes issued at the rate of two per year. The *TRANSACTIONS* were brought up to date after World War II by working on two volumes simultaneously, not by saving time through relaxation of editorial standards. We hope, of course, by improvement of our own efficiency and through greater cooperation of authors in preparing copy, to shorten the time of publication but we do not anticipate the production of "quickies." Ours is one of the best written and best printed publications in its field, and we propose to keep it in that position.

I should like personally to thank the members of the Editorial Board for their excellent work, and all of us on the Board wish to commend our long-suffering authors for their patience.

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

ROBERT S. CAMPBELL

LIMNOLOGY AND AQUATIC BIOLOGY

In recent years most Canadian fisheries biologists have been mainly concerned with problems of fisheries management or of fish culture in its broadest sense. These problems necessarily often involve some observations on limnology and aquatic biology. Three individuals—Dr. D. S. Rawson of the University of Saskatchewan, Dr. R. R. Langford of the University of Toronto, and Dr. F. R. Hayes of Dalhousie University—with their students and associates, have recently made particularly noteworthy contributions in these fields.

Dr. Rawson has recently completed a series of papers describing at length the limnology of Great Slave Lake and many features of its aquatic biology. He has also demonstrated the influence of lake morphometry on biological productivity. He has shown that in the larger lakes there are inverse correlations between mean depth and standing crop of net plankton, between mean depth and quantity of microscopic bottom organisms and between mean depth and long-term fish production.

Dr. Langford has carried on for several years a major experiment in fertilizing lakes in the Precambrian formation with commercial fertilizer. He has concluded that such fertilization is not a practical way of increasing biological productivity in oligotrophic lakes in Ontario.

Dr. Hayes has made important observations on the effect of adding commercial fertilizers to eutrophic ponds and small lakes. He has been particularly interested in why phosphorus rapidly disappears from solution in lake water and has studied the phenomenon in detail by using radioactive phosphorus. He finds that most of the phosphorus added as fertilizer is lost to the lake bottom and to other solids and only a small part is used by the plants (including phytoplankton). Bacteria at the mud-water interface seem to play an important part in the process. Surprisingly enough, practically all the phosphorus lost becomes concentrated within less than one millimeter of the mud-water interface.

The limnological characteristics of North American alpine lakes have been documented in recent years by Dr. D. S. Rawson and Dr. R. W. Pennak.

In 1948, through passage of P. L. 845, 80th Congress, the U. S. Public Health Service was specifically charged with certain responsibilities relating to water pollution control within the United States and provided with limited enforcement authority so far as interstate waters are concerned. Among the research contributions of this agency have appeared "Critical Review of Literature on the Toxicity of Industrial Wastes and Their Components to Fish" in several categorized parts, by Doudoroff and Katz, and "Bio-Assay Methods for the Evaluation of Acute Toxicity of Industrial Wastes to Fish" by Doudoroff, *et al.* Selected bibliographies have been made available as follows: "Handbook of Selected Biological References on Water Pollution Control, Sewage Treatment and Water Treatment" and "Selected Bibliography of Publications on Industrial Wastes Relating to Fish and Oysters." A third, "A Selected Bibliography of Publications Relating to Undesirable Effects Upon Aquatic Life by Algicides, Insecticides and Weedicides," is in press. In addition, the U. S. Public Health Service supports and cooperates in State and interstate programs for control of pollution in the major river systems.

A significant contribution to pollution investigation is the "Water Quality Criteria" published in 1952 by the State Water Pollution Control Board, Sacramento, California.

Pollution problems in marine waters are being attacked by oceanographers. In Washington, mapping data on the lateral and vertical movements of water are being used to expedite the tracing of sulfite liquor distribution in certain critical areas of Puget Sound. Estuarine pollution is under study at a number of sites in California.

Progress in investigations relating to productivity of water and conducted by personnel of the Section of Inland Fisheries, Fish and Wildlife Service, are described by W. F. Carbine, Chief:

"No method has been devised for assessing the total productivity of inland lakes and streams. For several years now Fish and Wildlife Service

employees have been studying aspects of this subject. Preliminary work to date has been in the following areas with some encouraging results:

1. Absorption of organic and inorganic substances directly from the water by fishes. This involves uses of radio-active materials by chemists and biochemists (Dr. A. M. Phillips, Jr., Cortland Laboratory).

2. Bio-assay of natural fish food organisms from different ecological areas (Dr. A. M. Phillips, Jr., Cortland Laboratory).

3. Determination of an index of productivity in which periphyton production is correlated with various physical and chemical factors of water. A very interesting correlation has been found between periphyton production and the bicarbonate and sulfate content of a series of ten lakes. Further work is in progress which will determine the accuracy of this method of evaluation of productivity. (Mr. R. S. Nielson, California-Nevada Fishery Investigations in cooperation with various specialists in a number of fields).

4. The nutritional requirements of various species of phytoplankters using radio-active isotopes as tracers (Drs. Chipman and Rice, Special Shellfish Investigations).

5. The chemistry of water of the Gulf of Mexico with special emphasis on the vitamins and carbohydrates present in natural sea water (Mr. Albert W. Collier, Gulf Fishery Investigations)."

Progress in limnological investigations is indicated by a lessened reliance on the use of routine water quality analyses and a more critical investigation of limiting substances as nitrogen and phosphorus, and of trace elements. Hayes, Langford, Einsele, Hutchinson and others have made notable contributions in this field. Investigators are now more generally aware of the tremendous complexity of the nutritive dynamics and of the inadequacy of our present methods of analyses for critical study.

Many critical data in the study of limiting substances have come from the study of pure cultures of algae in nutrient media. One important development here has been the recognition of algal metabolites. Investigations, largely since 1940, by Rodhe, Rice, Lefevre, Pratt, McCombie and others have disclosed growth substances which are heat-labile, diffusable and anti-biotic. These substances, the nature of which is largely undisclosed, promise to contribute to the understanding of plankton blooms, plankton succession and algal toxins.

Researches on nutrition of algae by Lund, Rodhe, Gerloff and Skoog indicate that plankton algae are able to concentrate and store mineral nutrients, especially nitrogen and phosphorus. These stored materials may sustain plankton growth long after the nutrient supply in the water has fallen to a low level.

Better methods are being developed to measure water movements and determine their influence upon fish-food organisms and upon the fishes themselves. In this field, Mortimer and Bryson are well known for their intensive investigations of water movements in stratified lakes.

Recognition of the importance of integrated investigation in several related fields is recently more apparent. Chemists and fisheries biologists

are working together on studies of water fertility and fish production. There have been related studies of rivers and of the impoundments in the same watershed. In its broadest sense this idea is applicable to the integrated simultaneous social, economic, land use and wildlife investigations on an entire watershed as seen in the Connecticut River survey by the Yale Conservation Program, or the T.V.A. Development, or the "Pilot Plant" Watershed Program, approved by the 83rd Congress, for complete soil-conservation and flood-prevention treatment on 50 "pilot plant" watersheds in the nation. The need for this integrated investigational plan has been clearly stated by Dr. A. V. Tunison (correspondence):

"During the last few years I have begun to wonder if fishery management work is becoming a closed corporation for fishery biologists. Seldom does one see research being carried on by scientists in other fields which will affect fisheries. I am sure that, in reviewing the work . . . on poultry or dairy cattle, one would notice almost at once that (at any University) the husbandry people do not loom too large in the staffing of the college. Scientists from the fields of genetics, nutrition, physiology, pathology, and so forth, are constantly called in to assist in the overall project of improving poultry or dairy cattle husbandry. Why is this lacking in fisheries?"

Perhaps the outstanding example of an institution at which limnological and fisheries management problems have been attacked by a corps of specialists is the University of Wisconsin. Specialists from the Departments of Botany, Biochemistry, Physics, Meteorology and Soil Science have in the past and are at the present time engaged in basic research hydrobiology. The recent important contributions made by Bryson and Ragotzkie at Wisconsin concerning water movements in lakes and their influence upon the distribution of plankton are examples of the "team" idea at work. It is unfortunate that administrative bodies of other universities do not have the funds and prestige necessary to recruit specialists from these fields into work on hydrobiology, as has been done by the University Research Committee at Madison.

OCEANOGRAPHY

In Canada the study of oceanography is a joint undertaking of several governmental agencies under the Canadian Joint Committee on Oceanography. Considerable work has been done on the Atlantic and Pacific Oceans and a start is being made on a study of the Arctic Ocean.

On the Atlantic Coast observations have been made for some time and are continuing on water temperatures and salinities particularly on the Scotian Shelf, in the Gulf of St. Lawrence, and in the Bay of Fundy. The accumulated data show a complex picture of stratification because of varying salinities and temperatures that result from interaction between the outflow of fresh water from rivers and tidal mixing.

On the Pacific Coast details on temperatures and salinities have also been accumulated. Salinities off the Fraser River are found to fluctuate both seasonally and daily. The region of divergence of the North Pacific

Current has been located and has been found to fluctuate from year to year.

Dr. Dunbar, of McGill University, has done an extensive oceanographic survey on Hudson Bay and in neighboring waters. Much of his material has yet to be analysed but the study is obviously an important contribution to our knowledge of Arctic Seas.

Dr. Carl L. Hubbs of the Scripps Institution of Oceanography has contributed the following paragraphs:

Some outstanding recent work in oceanography has dealt with the productivity of ocean waters as related to trace elements and vitamin-like substances in certain water masses. The outstanding advances along this line have been coming from the Plymouth Laboratory in England, but of course are applicable throughout the world. Other recent oceanographic work pertaining directly to the fisheries has been the considerable expansion, both in theory and application, of the sonic detection of fish schools, along with the development of mid-water trawls to capture such fish on the high seas.

Probably the outstanding contribution of oceanography to the fisheries has come from the explorations of the Pacific Oceanic Fisheries Investigations near the Equator, where the productivity of the waters and the potential development of the tuna fisheries has been attributed to the vertical circulation of water associated with the equatorial currents. Other work on the physical and biological characteristics of the ocean as bearing on the tuna fisheries is being done by the California Department of Fish and Game and the Inter-American Tropical Tuna Commission.

In the California Cooperative Oceanic Fisheries Investigations evidence is accumulating to indicate that changes in the ocean currents, particularly in the Davidson counter current along the California coast, may well be correlated with the catastrophic decrease in the sardines. The relationship between temperature conditions and the successive spawning of sardines is being quantitatively elaborated in these investigations.

Another phase of biological oceanography with a bearing on the fisheries is the critical analysis of the red tide phenomena in the Gulf of Mexico.

FISHERIES MANAGEMENT

The administrators of the various Canadian fisheries are tending to rely more and more on the results of scientific research. Regulations based on guesses are gradually being replaced by regulations based on knowledge. This happy situation has progressed to the extent that some administrators risk public disapproval for the sake of important experiments in fisheries management. The following are examples of such experiments: (1) a recently opened fishery on Great Slave Lake, which is the fifth largest lake in North America, is officially regarded as an experiment in fisheries management—the effect of “liberal” commercial fishing regulations, mostly regulations recommended by biologists, are under close observation; (2) the effects of deliberately overfishing two Alberta lakes commercially have

been and still are being assessed; (3) the effect of a fairly intensive commercial fishery on adjacent sport fisheries is under study in Ontario. These experiments differ from "trial and error" administration in that continuous detailed scientific observations are taken over several years as a basis for assessing results.

There have been no noteworthy recent advances in the management of fisheries of the high seas apart from those more properly described under international relations. Inshore, action is being taken to see that the lobster crop is harvested when the lobsters are larger than formerly. Inland, near the Atlantic Coast, intensive control of predatory birds is being established as a tool of fisheries management, while control of predatory fish is also developing, particularly in connection with the promotion of better survival of young Pacific salmon.

Most Provincial Governments (they administer the inland fisheries) have recently increased the number of biologists permanently employed, as a step towards better management of their fisheries. Although no noteworthy major advance has occurred a multitude of local problems have been studied, and overall improvement in freshwater fisheries management has resulted. There has been a limited tendency to "liberalize" the regulations which apply to sport fisheries, particularly those in Alberta. There has not been the same tendency to "liberalize" the freshwater commercial fisheries regulations—however, a notable exception to this statement is recent action in Ontario which permitted the more efficient trap-nets to replace pound-nets on Lake Erie.

Liberalization of fishing regulations on warm-water species in the United States was investigated early in the Tennessee Valley Authority reservoirs and has now spread across the country, although local adoption has not always been based on conclusive local research results. This progress in bringing the public to accept the proper use of a resource suggests that conservation education can be effective. Whether such liberalization may be applied to flowing waters or to all species of fishes remains to be determined.

In contrast to the liberalization of restrictions on fishing for warm-water fishes, there is in Michigan a trend toward increasing regulation of sport fishing on trout streams. Higher size limits and restriction of angling to fly fishing only is being tried in a number of streams.

The staff of Great Lakes Fishery Investigations of the U. S. Fish and Wildlife Service, under the direction of Dr. Moffett, has made remarkable progress in the study of the lake fisheries. Life history of the sea lamprey and several other species of Great Lakes fishes is being investigated. Recent reports describe the method of control of the sea lamprey which employs electricity in the selective destruction of that predator. Critical studies by Hile, Eschmeyer, and others are following the population structure of Great Lakes fishes with emphasis on species of commercial importance, especially the lake trout in Lake Superior.

No major advances can be cited, but there is a continued interest in the increased utilization of rough fish, in stream improvement, and in

pond-fish culture including the raising of bait minnows. Underwater observations by means of diving equipment, underwater photography and underwater television, give promise of evaluation and improvement of commercial fishing gear, and of substantial contribution to our understanding of fish activity.

Some progress resulting from inter-state programs is evidenced by the publications of agencies such as the Upper Mississippi River Conservation Committee. The need is great for additional agencies free from petty state jealousies and hampering state politics.

There are appearing a number of outstanding research findings, applicable to fisheries management, which have come from effective use of the experimental method with wild fish populations. Excellent examples include Dr. Gerking's "Evidence for the Concepts of Home-Range and Territory in Stream Fishes," and Dr. Hayes' "Artificial Freshets and Other Factors Controlling the Ascent and Population of Atlantic Salmon in the LeHave River, Nova Scotia."

There is evidence of an encouraging trend in the preference of fishery administrators for men with the Master's training over men with the Bachelor's degree. Recognition of this preference is not always matched by a greater salary commensurate with the greater training. It is to be hoped that the value of the biologist with the Ph.D. degree in fisheries will become more widely recognized by fishery administrators.

The Committee is indebted to Dr. Raymond E. Johnson of the Fish and Wildlife Service for the following comments on the Federal Aid in Fish Restoration Program.

The Dingell-Johnson program, began July 1, 1951, has had two general beneficial effects nationwide in scope. The first is that it has made possible the establishment of research organizations in states which had none before, especially in the Plains states and the Southeast. The second is that the program has made available to the rising army of anglers much more fishing water, either by building new lakes or by buying access into lakes and streams formerly sealed off by private lands.

At the end of three full years of operation (June 30, 1954), there were 136 investigational projects in 47 states and territories, obligating 1¾ million dollars on fact-finding work. This sum amounted to 52 percent of all Dingell-Johnson funds available at the time. About 300 technicians are now employed on Dingell-Johnson projects and their average salary is rising steadily toward the \$4000.00 per year mark.

The research projects fall into eight general categories: (1) Statewide surveys of lakes and streams in the classical tradition, mostly in those many states which had no idea of the fish populations, chemistry, physics, or biology of their waters. At least 37 projects in 23 states work on this theme. (2) Angling harvests are studied widely. Nearly all states are finding that the catch in terms of pounds per acre is higher than expected, but not detrimentally high yet. (3) Lake and stream mapping projects both winter and summer, especially those using aerial photography and echo sounding equipment. (4) Individual problems on age and growth,

food habits, effectiveness of management techniques, etc. These are usually done by graduate students with two years of time and a subsidy from the Conservation Department. (5) Intensive, basic study on pond stocking and fertilizing problems. (6) Specialized research on fish diseases and parasites, and on the breeding of a furunculosis-resistant strain of trout. (7) Research on the effects of watershed management upon stream trout and smallmouth bass welfare, fish populations, and catch rate. (8) Marine research on coastal sportfishes on the west coast (especially California), in Texas, and in the middle Atlantic states.

The Committee suggests that:

- (1) The Dingell-Johnson program might emphasize investigations relating to:
 - a) The major problems of watershed management including soil erosion, water conservation and pollution as they relate to the fisheries resource.
 - b) The dynamics and management of small lakes.
 - c) The effects of rough fish removal on game fishes in large impoundments.
 - d) The population dynamics of fishes in large impoundments and methods of analysis and evaluation of these fish populations.
- (2) There be a greater use of Dingell-Johnson funds for fundamental research in fisheries management. New ideas are needed badly and basic research is the principal method to satisfy this end. Universities should not be expected to carry out all such work.

FISH CULTURE

In Canada more and more of the men directly concerned with increasing and maintaining fish stocks are concluding that fish hatcheries are not the cure-all of fisheries ills that the average citizen believes. Many now regard fish hatcheries as useful only to establish (and maintain if necessary) species where they do not exist, to re-establish fish populations following catastrophic annihilations and to provide fish for experimental work. Some feel that, in addition, hatcheries which produce game fish could increase catchable fish stocks in places where fish now exist if the correct techniques were developed. Several fish hatcheries have been closed following scientific investigations which showed that they were not increasing the catch. Others apparently still operate only because public opinion overrides the evidence that their operation is probably not justifiable.

In view of these facts it is not surprising that there has been little recent improvement in hatchery technique. Instead, the recent trend has been to place emphasis on fish culture in its broadest sense, and to attempt to increase stocks of fish by means other than fish hatcheries. In particular, emphasis has been put on assisting those species which ascend rivers and streams to spawn. Obstructions have recently been removed from many such streams—the most outstanding case was the removal of a tremendous rock slide which blocked a canyon of the Babine River and hindered

Pacific salmon from reaching their spawning grounds. Fish ladders that really work have at last been developed. Several have been installed recently to assist spawners to bypass natural and man-made obstructions. A well-publicized example is a recently built fishway at Hell's Gate on the Fraser River. Artificial spawning grounds have been developed in several western streams. Migrant steelhead trout are now planted downstream in certain streams in Washington and British Columbia where low summer water levels exist because of water use for irrigation.

There has been little recent progress in the production of fish in farm ponds except to re-emphasize that methods found successful in one geographic region are not necessarily applicable in another.

It is not surprising that nutrition and disease are still two of the most important problems confronting the fish culturist of cold-water fishes. Government agencies engaged in the rearing of trout and salmon all find hatchery feed the greatest single expenditure (labor costs excepted) and fish diseases have become a limiting factor in the use of certain hatcheries. Fortunately, persons specifically trained to investigate these problems are now coming to the aid of old-time fish culturists.

Research on nutritional deficiency syndromes and basic nutritional requirements through the use of synthetic diets is now progressing at an accelerated rate. Other nutrition work involves the use of locally available products in varying combinations in the search for the most economical and complete diet through actual feeding tests. The U. S. Fish and Wildlife Service, State Universities, and nearly all fish cultural agencies are working at this level to some degree. Much interest in dried pellet type feeds for hatcheries has also been shown.

Diseases of bacterial or virus origin are most serious. In general myxobacteria are responsible for or are associated with many hatchery diseases. Bacteria of this group attack both fingerlings and adults and are a most serious problem in certain areas. Professionally trained bacteriologists are rapidly joining the staffs of most agencies responsible for raising cold-water fishes.

Much improvement in the use of hatcheries and hatchery products is still urgently needed. All too frequently a hatchery program is operated as a distinct and separate function of a Fish and Game Agency rather than as a branch or tool of a Fisheries Management Division. Hatchery superintendents, sportsmen, forest rangers, and many others who have no knowledge of ecology or fish populations are given full charge of fish plantings. Fish released by such individuals frequently have less chance for survival than a palm tree in Chicago. Productive, and consequently successful hatchery programs can be expected only where trained fishery biologists are handling planting programs and are judiciously using hatcheries as only one phase of a fisheries management program.

Intensive study is needed on the aspects of wildness or lack of wildness in hatchery-reared fishes; and on the reasons for death or survival of hatchery-reared fishes when released.

PHYSIOLOGY

Odor perception in fishes has been investigated by Hasler and Wisby in Wisconsin, and by Alderice, Brett, Idler and Fagerlund of the Fisheries Research Board of Canada. Their observations have been related to survival of migrating salmon, to orientation of fishes to the parent stream and to the use of fishes for the commercial detection of certain trace contaminants.

Over the past few years there has been an increasing interest in the basic nutritional requirement of fishes. Laboratories in New York and Washington have been working on the vitamin requirement of trout and salmon. By means of synthetic diets, the need for approximately 8 members of the B complex has been established. Such basic studies have resulted in the control of several nutritional disorders. The Washington laboratory is also working on the amino acid requirement of salmon as well as the need for many of the other trace factors of nutrition.

Interest has recently centered around the metabolic activity of trout and the application of this activity to hatchery practices. It has been shown that the accumulation of metabolic products is a limiting factor in both holding fish in ponds and shipping in tanks. During the past couple of years methods for reducing metabolic activity have been explored with the results that chemicals, starvation, and water temperature have all been found to be effective. Such results can be applied to shipping trout over long distances.

Some attention has been directed toward the chemical content of natural food and its comparison with hatchery diets. All of this work has been preliminary in nature, but from the results obtained, it does appear that much can be gained from these studies. It is suggested that these studies should be stressed and the results applied to hatchery feeding methods.

In years past little attention has been paid to the nutritional role of dissolved substances in relation to fish life. The coming of radio-active isotopes in large quantities at a low cost has opened this whole field to fishery investigators. Recent work has shown that calcium, phosphorus, and cobalt are absorbed directly from the water by the fish. Such information should be of value to both hatchery managers and field workers. This phase of fish physiology deserves considerably more attention.

It has been only recently that the chemical content of hatchery trout has been investigated. In years past the criteria for the value of hatchery practices has been the gain in weight of the fish, their mortality and the number of pounds of food necessary to produce a pound of fish flesh. Little attention has been paid to the product as such. Studies have shown that drastically different trout may be produced, chemically speaking, by different types of diets. Such results certainly warrant further investigations in terms of the value of the various types of trout that may be produced.

The trend toward basic problems of fish nutrition and physiology should

be encouraged and this type of work might well be stressed. Through this type of investigation, it should be possible to uncover many of the complex problems that now face both the hatchery manager and the field worker.

Dr. Carl L. Hubbs has contributed the material that follows:

Outstanding physiological investigations include those by Fry, Hart, Black, and other Canadians on the resistances and responses of fishes to temperature changes; by Kleerekoper of McMaster University on the reaction of fishes to sounds; and by T. J. Walker of the Scripps Institution of Oceanography on the functions of the lateral line system in fishes.

The techniques of serology and of paper partition chromatography are also being applied, particularly in the University of California, to the problems of the separation of species and races in fishes. As part of the California Cooperative Oceanographic Fisheries Investigations some outstanding work is being done on the responses of fishes to electrical currents. These studies will eventually bear on the problem of electro-fishing.

AGENCIES

Increased support of productive research and dissemination of knowledge pertaining to fisheries is to be credited to many agencies and is a mark of continuing advance in the fisheries field.

Among agencies not devoted solely to the fisheries field the Wildlife Society is to be acknowledged for its support through publication of many fishery papers in the *Journal*.

Among the federal agencies the Fisheries Research Board of Canada and the U. S. Fish and Wildlife Service have made substantial contributions.

State universities, Cooperative Wildlife Research Units, federal and private institutions now offer extensive opportunity for training in fishery biology and all fields relating to fishery management. There are 187 laboratories (marine and freshwater) in North America offering facilities for research and training; Frey listed 66 institutions in the United States where limnology was taught in 1953. Some universities are offering extension courses in fishery conservation to the lay public.

Recent advances, in addition to the increased opportunity for training, include improved relations between university, state and federal agencies and (in the minds of many) a more able and somewhat more practical research program in the state universities.

The Sport Fishing Institute, established in 1949, promises to become an effective force in the support of improved standards in the hiring of fishery personnel, of improved wages and of a recognized place for fishery research in the state conservation organization. The institute's reprint distribution service has resulted in placing some 14,000 reprints in the hands of fisheries investigators. Their *BULLETIN* offers a nation-wide current digest of new developments and problems in the fields of fishery biology and management.

The Federal Aid in Fish Restoration Program has stimulated investigation and the development of new fishing waters.

Although most state departments of conservation support fisheries research to a limited degree, few maintain a fishery research division of trained personnel free to function without excessive curtailment by the demands of "trouble shooting," political expediency and excessive administrative restriction. One has the feeling that in many state departments fisheries technicians are tolerated because their presence suggests a certain mark of progressiveness; but little use is made of their research contributions in regulation and management procedures.

PUBLICATIONS

Publications, descriptive of the fish fauna of one state or of a geographic area, which stimulate interest in fisheries, continue to appear. At the time of writing we are informed that the monographic "Fishes of Ohio" by Dr. M. Trautman is completed.

The appearance of good recent text books in fisheries and related fields is indicative of current progress. Books include the first fishery management text "Fishery Science" by Rounsefell and Everhart; Ruttner's "Fundamentals of Limnology," translated by Frey and Fry; and Davis's "Culture and Diseases of Game Fishes."

Successful attempts to expand the horizon of the layman who has a passing interest in fishery problems have included: "Iowa Fish and Fishing," Harlan and Speaker; "Life in Lakes and Rivers," Macan and Worthington; "Harvest of the Waters" and other publications of the Department of Fisheries, Canada.

Conservation education in fisheries has produced films like "The Great Lakes Invader (The Sea Lamprey)," by the Fish and Wildlife Service, and children's texts like "Tommy Trout," by R. W. Eschmeyer. The Sport Fishing Institute's BULLETIN carries fisheries conservation to the layman directly or indirectly through outdoor writers, conservation officers and legislators.

Substantial contributions to research progress are to be credited to Dr. Carlander for his cumulative "Handbook of Freshwater Biology" and to the Research Council of Canada for their publication "Bibliography of Canadian Biological Publications." Other items of value include "Survey of Sport Fishery Projects, 1954," "Doctoral Dissertations on the Management and Ecology of Fisheries" and "English Translations of the Fishery Literature," all published by the U. S. Fish and Wildlife Service.

An unusual contribution is the "Directory of Hydrobiological Laboratories and Personnel in North America," by Robert W. Hiatt and associates, prepared under the auspices of the Advisory Committee on Hydrobiology of the Office of Naval Research and issued by the University of Hawaii Press.

OUTSTANDING NEEDS IN FISHERIES

A review of this report leaves members of the Committee much impressed by the exceptional advances and the promise of even greater achievements in many of the fields of fishery biology. At the same time there remains the depressing realization of numerous long-standing weaknesses in the fisheries field. The Committee takes this opportunity of emphasizing to the Society some of the outstanding needs in fisheries:

1. Progressive improvement in relations between federal, state and university agencies.
2. More extensive use of the overall research approach, embracing simultaneous consideration throughout an entire watershed of problems social, economic, land use, wildlife, water conservation, etc. Elaboration of the research attack to include physicists, chemists, soils technicians and other specialists for a concerted approach to a common problem.
3. Greater recognition of the place of research among state conservation agencies; and the need for trained personnel at the Master's and even Ph.D. levels among fishery biologists.
4. More extensive use of the findings of the fisheries technician as a basis for regulation and management.
5. Incorporation of the hatchery program into the fisheries management division of the Fish and Game Agency, with the employment of technically trained supervisory personnel.
6. Salaries for trained personnel commensurate with their training.
7. Some effort toward standardization of methods in fisheries management and in limnology.
8. More rapid progress in the standardization of scientific and common names of fishes.
9. A lessened use of processed pamphlets by both state and federal agencies. These pamphlets are sometimes immature and are so restricted in distribution that they serve as an inadequate medium for distribution of knowledge.
10. A fisheries abstracting service or review patterned after or incorporated in *Wildlife Review* (Fish and Wildlife Service).

In concluding this report, the Committee endorses and submits to the Society a proposal made by Dr. D. S. Rawson, namely: that the rather general and extremely broad assignment of the Committee on Hydrobiology and Fish Culture, as set forth in the Constitution, be revised. In its place, it is proposed that the Society define or list a series of more restricted special subjects. One special subject might then be reviewed thoroughly each year, taking the various subjects in turn. This would appear to be more profitable than the present annual broadcast attempt to touch upon many extensive fields ranging from fish physiology to oceanography.

COMMITTEE ON COMMERCIAL FISHERIES

ROBERT W. SCHONING

Your committee patterned its report along the lines of ones submitted in previous years. In that respect, information relative to the trends of the commercial landings during 1953 throughout the United States, Alaska, Hawaii, and Canada was included. In addition, recent interesting developments or innovations in the pursuing, capturing, processing, and marketing of fish and fish products are mentioned. The significant number of these in all phases of the fisheries industry indicates a healthy condition of awareness and desire for improvement and betterment—an encouraging sign of our times.

As is very often the case in the preparation of a report of this type, many people do the work and one person usually receives the credit. Each member of the committee very generously donated his services whenever a request for his help was made. Mr. A. H. MacDonald was initially appointed to the chairmanship of this committee, but resigned when he left his former post in Canada to accept a position in Ceylon. Prior to his departure, Mr. MacDonald laid the groundwork for the Committee Report. In my position as interim chairman, I merely, with a minimum of effort, completed the job so competently begun.

Requests for information were sent to a number of organizations and each was extremely cooperative and helpful. A very excellent and comprehensive discussion of the commercial fisheries of Canada in 1953 was provided by Mr. W. C. MacKenzie, Director of the Markets and Economics Service of the Canadian Department of Fisheries. Because it covered all phases of the Canadian Fisheries so very adequately, even though it was of considerable length, the committee included Mr. MacKenzie's report almost *in toto*. A concise summary of commercial fishery activities in the United States in the past year was contributed by Mr. A. W. Anderson, Chief of the Branch of Commercial Fisheries of the Fish and Wildlife Service. A considerable amount of very useful material was generously offered by a number of other individuals and organizations. Their invaluable assistance is hereby acknowledged with sincere appreciation. Our task was made much easier by their efforts.

The United States and Alaska catch of fishery products in 1953 totaled about 4.45 billion pounds, valued at approximately \$345 million to the fishermen. Compared with the previous year, this was an increase of about 1 percent in volume, but a decline of about 4 percent in value. Had there not been a spectacular gain in the production of menhaden, the 1953 catch would have been far below that of the previous year. The catch of menhaden totaled about 1.7 billion pounds—350 million pounds above the previous year's production and the largest catch of this species in history. The menhaden catch was about 200 million pounds above the 1936 record pilchard production of 1.5 billion pounds, which had previously been the largest catch of a single species taken by United States fishermen.

Far below normal runs of salmon and herring in Alaska resulted in a sharp reduction in the catch of these species. The catch of salmon in the Pacific Coast States was larger than in 1952. This was due to an increase in the run of sockeye salmon on their way to spawning grounds in the Fraser River, and the large catch of pink salmon which appear in Puget Sound waters biennially in odd-numbered years.

The Washington and Oregon albacore tuna fishery, which amounted to less than one million pounds, was nearly a complete failure. This fishery yielded a peak catch of 34 million pounds in 1944, and has since averaged 10 to 15 million pounds annually. The once thriving Washington and Oregon trawl fishery for flounders and rockfish operated far below the ability to take these fish due to limited markets for their fillets.

In California the pilchard catch was almost a complete failure amounting to only about 5 million pounds, compared with an annual average of well over 1 billion pounds during the period from 1934 to 1945. The California catches of Pacific and Jack mackerel were, likewise, below normal, and landings of tuna were somewhat less than in 1952. The catch of anchovies, however, was the largest in history.

The 1953 catch of shrimp, which is taken principally in the Gulf of Mexico, amounted to about 235 million pounds—the largest production in the history of the fishery.

Spectacular increases occurred in the Middle Atlantic and Chesapeake catches of menhaden. About 1 billion pounds of these fish were landed in the States of New York, New Jersey, Delaware, and Virginia in 1953 compared with less than 600 million pounds the previous year. The catch of these fish in the South Atlantic States declined sharply while that in the Gulf was somewhat less than in 1952.

The catches of most major items in the New England States showed a sharp decline. Landings of herring in Maine were only about two-thirds as large as in the previous year. While deliveries of ocean perch to Maine ports were almost identical with those of a year ago, landings at Massachusetts ports were 27 percent under those for the previous year. Massachusetts landings of cod, haddock, and mackerel all declined sharply in 1953 compared with those of the previous year, although catches of whiting and scallops were considerably greater.

An outstanding development in the fisheries of the United States during 1953 was the rapid expansion of the fish stick industry. Relatively slow during the first few months, production accelerated rapidly and by the end of the year the output amounted to 7.5 million pounds. And even then firms were having difficulty keeping up with their orders. Consumer acceptance of fish sticks has been so widespread that some sources expect them to do for the fishing industry what fruit juice concentrates have done for the citrus fruit trade.

Fish sticks are uniformly shaped boneless pieces of fish dipped in batter, breaded, and frozen in consumer-sized packages. Closely resembling french-fried potatoes in appearance, they can be purchased in precooked or uncooked form. The precooked sticks, which have been deep-fat fried

before freezing, are easily heated in the oven at home for serving. The uncooked sticks are designed for those housewives who prefer to do the frying themselves.

Because they are of uniform size and weight, a housewife knows just how many she requires for a given number of persons to be fed. The regular package usually holds ten sticks each weighing one ounce. A cocktail size as well as an institutional pack of 72 sticks has been developed. The latter has proved popular for the school lunch program. These sticks provide two ounces of protein essential to a growing child's health.

During 1953 the sticks were manufactured from both imported and domestic fish, the major portion, however, being made from imported cod. By early 1954, the number of plants producing sticks had increased several fold, and such species as pollock, salmon, halibut, whiting, and Pacific true cod were being used.

The United States' imports and exports of edible fishery products showed increases in 1953 compared with those of the previous year. Large increases in imports of fresh and frozen tuna, canned tuna, and sardines occurred. The outstanding development in the export market for fishery products was the sharp increase in shipments of inedible fish oils principally to West Germany and the Netherlands. Total exports of these oils amounted to nearly 105 million pounds compared with less than 53 million pounds the previous year.

A recent development in the field of fishing gear is the use of a new type of purse seining equipment in the Puget Sound salmon fishery. In place of the conventional turntable, a large drum or reel mounted on the stern of the vessel is used for setting, rewinding, and carrying the purse seine. Although one such drum seiner has been fishing out of Bellingham, Washington for several years, the first general trend toward the use of this new method in the United States became noticeable at the start of the 1953 season at which time 11 other seiners had been converted to this type of gear. The system originated in Canada, where a number of British Columbia fishermen have been operating drum-seine boats successfully for several years.

Doubts were expressed at the beginning of the 1953 season by some fishermen as to the ability of drum seiners to catch sufficient numbers of salmon, especially in deep water and tide rips. A number of problems in operating the new gear were encountered initially, but results indicate that most of the drum seiners enjoyed a successful season. Many additional purse seiners are expected to be converted for drum seining in the 1954 season, and some observers feel that a revolution in the purse seine fleet is under way.

The chief advantages of this gear are that it reduces the number of crew members required to operate the boat; it allows a set to be made in much less time; and it hauls the net by power so that much less labor is required by the fishermen.

In the Great Lakes, the experimental sea lamprey program of the Fish and Wildlife Service in Lake Superior had its first full season of operation

in 1954. A total of 44 electrical barriers blocked known and potential sea lamprey spawning streams along the south shore from Sault Ste. Marie to the Michigan-Wisconsin border. Comparisons with 1953, when 10 barriers were operated part of the season, indicated an increase in the abundance of sea lampreys in eastern Lake Superior, but results from newly installed devices in central Lake Superior were more encouraging. Failure of 22 of 28 barriers west of Marquette, Michigan, to take any lampreys at all suggests that this parasite may not yet be firmly established in the central and western areas. Evidence that the greatest concentrations of sea lampreys are confined to the eastern part of Lake Superior and the fact that the Canadian Federal Government and the Province of Ontario have initiated a control program on the Canadian shore of the lake give cause to hope that action has been started early enough to prevent a complete collapse of the lake trout fishery such as occurred in Lakes Huron and Michigan.

In these same lower lakes the fishing industry faces still another threat in the changes in the fish populations that have followed the disappearance of the lake trout. Principal food of lake trout was the bloater, a small species of cisco or chub of almost no commercial value. When populations of lake trout were large, the annual consumption of bloaters ran to untold millions of pounds. Now that this predation has ended, the numbers of bloaters have increased enormously, creating a nuisance to fishermen by becoming entangled in their nets and offering stern competition for food and space to the valuable species of chubs. The situation is made even more difficult by the continued predation of the still numerous lampreys on the larger and better chubs. In recognition of the seriousness of the problem, the Fish and Wildlife Service research vessel *Cisco* is making an intensive study of conditions in the chub fishery of Lake Michigan.

Far below normal runs of salmon and herring resulted in a sharp reduction in the catches of these two species in Alaska. The salmon fishery realized the smallest pack since 1921. Although the catches were very poor, the condition was not unexpected as it was anticipated that the runs would be small, and their magnitude closely approached the predictions of the Fish and Wildlife Service. However, the pink salmon runs in Southeastern Alaska were a near failure, considerably below the anticipated. The condition is quite puzzling because the pink salmon escape-ments in this area in the parent year of 1951, and the downstream migration from that spawning were both relatively good. Consequently, a fair season had been expected. The near failure which resulted can only be attributed to extremely poor ocean survival, the cause of which is presently unknown. It is particularly puzzling because in the adjacent areas of northern British Columbia, the pink salmon runs were relatively good in 1953.

The herring fishery was equally poor with a continued low abundance in Southeastern Alaska coupled with the still unexplained absence of herring at Kodiak Island.

Inasmuch as the British Columbia herring fishery is conducted during the winter months, an experimental season was permitted in Southeastern Alaska in 1953 to determine if the offshore herring populations in this area also might be moving inshore in a similar manner during the winter. The results were extremely disappointing, however, and the few herring which were taken were all of the younger year classes.

In 1953, for the first time, biologists from Canada and the Fish and Wildlife Service conducted a joint aerial survey of the herring spawning grounds in British Columbia and Southeastern Alaska. It is hoped that this joint operation can be continued in order to evaluate the extent to which the known spawning beaches are used by herring.

Although king crab have been known to be present in Kachemak Bay in Cook Inlet and in the Kodiak area, they have been taken for commercial purposes only in very limited quantities prior to 1953. However, that year, particularly in the Kodiak area, a fishery was conducted by 10 or 12 boats throughout the winter months. The majority of the catch was marketed fresh or frozen with only a small amount being canned. Close surveillance of the fishery will be maintained to determine if there is a definite continuity of moulting time, with the idea of establishing a closed season during that period. Careful study of the fishery from its inception facilitates maintaining it on a sustained yield basis.

The Research Division of the Alaska Department of Fisheries, a relative newcomer to the ranks of management agencies, continued with its fine work. The majority of its efforts are, of course, directed toward salmon work. Construction was started late in 1953 on a small research station and experimental hatchery at Kitoi Bay on Afognak Island near Kodiak. Initially the program will involve basic studies on the artificial propagation and stocking of sockeye salmon. The Alaska Department of Fisheries inaugurated its king crab studies in 1953 as a result of the increasing importance of this relatively new industry to the economy of the area.

The consumption of fish by hair seals has been estimated by various researchers to be of considerable magnitude. Realizing the importance of controlling these predators, the Alaska Department employed skilled seal hunters who accounted for an estimated 6,800 of these undesirable fish eaters in the past year. On occasions dynamite was used very effectively in dispatching numbers of them.

Sport fish propagation and management was continued in close cooperation between the department and local sports groups.

The 1953 commercial landings in Hawaii were valued at \$3.8 million and amounted to 18.8 million pounds, of which 16.8 million pounds consisted of offshore pelagic species—chiefly skipjack, yellowfin, and bigeye tuna. The inshore fisheries, mostly for species living on or near the coral reefs and caught by traps, surround nets, and hand lines, are relatively small and unimportant. Of the offshore fisheries, the livebait fishery for skipjack is the most important and provides canned tuna for both home consumption and export.

The Territorial Board of Agriculture and Forestry Division of Fish and Game, is investigating the life history, abundance, and management policies for inshore species. The baitfish problem is receiving considerable study also, with particular attention being directed toward their mortality, developing more efficient gear for their capture, and the introduction of potential baitfish species.

The Pacific Oceanic Fishery Investigation of the U. S. Fish and Wildlife Service has been engaged in exploring the central Pacific area for potential tuna resources for about four years. The investigations of this laboratory have been divided along three principal lines of endeavor. First, they have investigated the central Pacific from about 110° W longitude to 180° , and from about 30° N to 10° S latitudes. Within this area, concentrations of yellowfin tuna have been located in a 300-mile wide and 2,000-mile long band near the Equator, extending from about 5° N to the Equator, and from about 140° to 170° W.

The method of locating and charting this resource is somewhat unique in that the oceanographical and biological means were used to describe the ocean circulation and locate areas of enrichment. Then by experimental fishing, using several techniques and considering the findings from the biological and physical oceanography, large concentrations of deep swimming yellowfin tunas were located.

A modified type of Japanese longline fishing gear was finally adopted as the most efficient type of gear for sampling these yellowfin. Recently commercial fishing trials by two west coast fishing vessels produced 210 tons of tuna in about four months of intermittent fishing. However, for the present, one of the industry's major problems is the discoloration of some of the larger fish on canning.

The second promising project being investigated is the distribution, movement, and abundance of skipjack in the vicinity of the Hawaiian Islands and the related oceanographical conditions. In the past a small commercial fishery, operating within 50 miles of the home islands, has produced about 10 million pounds of skipjack each year. Research has indicated that the islands themselves may not be an important factor in the abundance of skipjack in the central Pacific, although probably the distribution of the tuna in the vicinity of the islands is affected by the land masses. POFI research vessels, scouting hundreds of miles offshore, have located large concentrations of skipjack schools. If further studies establish their abundance and location, and should research on artificial bait substitutes be successful, the Hawaiian skipjack fishery may be expanded to several times its present size.

A third major project just getting underway is the oceanographical and biological investigation of the region north of Hawaii where two major current systems, the easterly flowing North Pacific Drift and the westerly flowing North Equatorial Current, adjoin one another. In this region of temperature and current boundaries, preliminary reconnaissance cruises indicate turbulence and enrichment of the surface layers accompanied by higher than normal amounts of biological productivity. Large, adult alba-

core tuna, averaging 60 pounds in weight, were taken from the vicinity of this current boundary during one experimental fishing cruise. Future investigations are planned to more definitely locate and define the extent of these stocks of tuna.

For several years following World War II the Canadian fishing industry made generally uninterrupted progress in both the economic and technological sense. During late 1952 and the first half of 1953, however, the industry was characterized by a greater degree of uncertainty than had existed previously. This uncertainty was due to disquieting developments in the field of export trade along with other problems, some of which proved to be temporary in nature.

Market conditions were generally depressed at the beginning of 1953. Currency and price difficulties provided obstacles to trade in some traditional markets, and surplus stocks of fishery products, at home and abroad, caused considerable concern. Prices offered to the fishermen as the various seasons opened were lower for most of the major species than they had been in the previous year. As the year progressed, however, conditions improved considerably. Markets became available, stock positions approached normal and prices at the end of the year were stabilized at improved levels.

Although total production in 1953 was only slightly below 1952 levels, with regard to both quantity landed and value to the fishermen, results in the different fishing areas varied considerably as between the two years. On the west coast there was a return to generally normal operations after a year troubled by strikes and lay-offs in the salmon and herring fisheries. In the Maritimes and Quebec, total production was about normal but dropped well below the near record 1952 level. Newfoundland landings also fell considerably in 1953. There was a slight increase in quantity landed in the freshwater fisheries.

New vessel construction on the west coast continued to decline from the peak year of 1951. Low incomes received during 1952 and rising production costs were contributing factors. There was a significant increase in the number of gillnetters operating during the year, but not so in trollers and seiners.

The trend in new vessel construction in the Atlantic area reflected the increasing emphasis on fresh fish production and the decline in production of salt fish. One new trawler, 42 new draggers, and several long-liners were added to the mainland fleet. The withdrawal from the groundfish fishery of a number of small draggers partly counteracted the effect of the new additions. The growing Newfoundland fleet was increased by six new trawlers and draggers and a number of long-liners and Danish seiners.

There were further reductions in the number of salt banking dory schooners on the mainland and in Newfoundland. Those continuing to operate landed chiefly in mainland ports. Only 14 of the 29 Labrador floaters which operated during 1952 continued to operate in 1953, and there were further reductions in the number of small trap and trawl boats.

Two filleting plants, one built to replace a plant razed by fire, the other

a renovated plant under new management, began operations during the year in Nova Scotia. In Newfoundland one plant was completed and construction was begun on two others. The completed plant will produce specialty products such as breaded fillets and fishsticks for the U. S. market. Several freezing plants in the latter province were inoperative for a good part of the season.

As part of the fisheries development program in Canada, a committee was set up in January 1951 to study the Newfoundland fishing industry. The committee was composed of representatives of the Newfoundland fishermen, the fish processors and exporters, the Newfoundland Department of Fisheries and Co-operatives, and the Canadian Department of Fisheries. An expert research staff carried out investigations into all phases of the industry on behalf of the committee. A report, presented in May, 1953, contains recommendations based on the committee's findings. These recommendations constitute a proposed program of integrated activity on the part of the federal and provincial departments of government as well as private enterprise. The main objective of this program is to raise the individual fisherman's income through increased productivity. Some of the proposals made are already being carried out including attempts to locate new fishing grounds and experiments with different types of fishing vessels. Other proposals necessarily require more study and planning before they can be put into effect, involving, as they do, the relocation of the population along the north shore around suitably located processing plants connected by new roads to the arterial highways.

A partial solution to the problem of loss compensation for fishermen engaged in the sea fisheries was provided in 1953 when the Canadian Government established the Fishermen's Indemnity Fund. Coverage for vessels ranging in value from \$250 to \$7,500 became effective in July, and a companion plan covering lobster traps went into effect in the fall of 1953. The yearly premium for vessel coverage is one percent of the appraised value. In cases of total loss the fishermen will receive 60 percent of this value, and in cases of serious damage, 30 percent with an additional indemnity of 85 percent of the amount by which repair bills are in excess of the 30 percent minimum. Premiums paid for lobster trap coverage vary according to the appraised value and the length of the lobster season in the area.

By the end of May 1954, 1,783 certificates of eligibility had been issued for vessels. The total appraised value was \$2,660,500 and premiums collected amounted to over \$26,000. Loss and damage claims amounted to \$17,500 involving 19 vessels. The number of certificates of eligibility for lobster traps issued amounted to 771 involving 125,243 traps. Premiums collected totalled \$14,300 and loss and damage claims amounted to \$15,900.

The outstanding feature of 1953 production in the Atlantic area was the pronounced drop in cod landings. This accounted for over 50 percent of the overall decrease in mainland landings and almost 80 percent of the decrease in Newfoundland landings. Total production on the mainland

dropped from 777 million pounds valued at \$35.2 million in 1952 to 684.5 million pounds valued at \$33.4 million in 1953. Newfoundland production dropped from 575 million pounds valued at \$13 million to 470 million pounds valued at \$11.4 million.

Landings of groundfish other than cod increased slightly in 1953 with rosefish landings showing the greatest percentage increase. Prices for all but halibut were lower than in 1952.

The pelagic species were in short supply in 1953. Catches of herring, sardines, mackerel, and alewives were smaller than in the previous year. Smelt landings increased but prices were low. Prices for the other species compared favorably with those of 1952.

The very good prices for lobster provided virtually the only strong point in the year. Although landings were slightly lower on the mainland, the increase in price was sufficient to raise total returns to the fishermen above the 1952 level. Landings were higher in Newfoundland in 1953 and prices reached an average high of 26 cents, 3 cents above the 1952 average high. More lobster was marketed in the live form in 1953.

The groundfish fillet industry, which has expanded remarkably since the war, met its first check when the U. S. market weakened in the latter part of 1952. A variety of factors contributed to this market situation including the high stock position and the downward trend in food prices generally. Lower prices on the U. S. market were reflected in the lower prices paid to Canadian fishermen in 1953.

Groundfish fillet production amounted to 99.5 million pounds as compared with 108 million pounds in the previous year. These figures include Newfoundland production which amounted to 38 million pounds in 1952 and 35 million pounds in 1953. The reduction was mainly in cod fillet production. Increased demand in recent years for fillets of haddock and rosefish, plaice and other flatfish has been at the expense of cod. Reduced production of groundfish fillets in Canada and the U. S. during the year contributed to the improvement in the stock position. Another factor was the increasing popularity of fishsticks which are made from blocks of frozen fillets. Prices at the end of the year showed some improvement over the opening prices and were expected to remain at this improved level during 1954.

Production of saltfish continued to decline in 1953 on the mainland and in Newfoundland. Despite this fact the industry continues to be of major significance in Newfoundland. Production of the two major cures on a dried weight basis amounted to 509,000 quintals, a 17 percent decline from production in the previous year. The decline was mainly in the production of shore cured light salted cod.

Unsold stocks from the 1952 cure, on hand in Canada and France at the beginning of the new production season, had a disquieting effect on the export trade. Lower prices necessary to move the surplus stocks affected prices offered to the fishermen for 1953 production. In Puerto Rico and Jamaica, ceiling prices on imports of salt fish were lowered and maintained at the lower levels throughout the year.

The market was strengthened somewhat by the announcement of a federal government purchase of saltfish valued at \$1 million for relief purposes in Greece and Korea. In October the Brazilian market became available to Canadian exporters after having been closed for some time and a substantial volume of trade resulted.

Early in 1954 the Canadian Government reached agreements with the Governments of Spain, Portugal, and Italy which would place Canadian sales of dry salted codfish in these markets on a more stabilized and permanent basis. As part of the trade agreements which were reached with Spain and Portugal in May 1954, these countries agreed to make available, import licenses and dollar exchange for minimum annual imports from dollar countries of 2,000 and 3,000 tons of dry salted cod, respectively. Under an arrangement made in June 1954, the Government of Italy agreed to make dollars available for the purchase of Canadian salt cod valued at \$3.1 million during the period July 1, 1954 to June 30, 1955.

An exceptionally good pack of better grades of salmon and a record fall catch of herring highlighted 1953 production on the west coast. Total landings in the area amounted to 542 million pounds valued at \$31.8 million as compared with 405 million pounds valued at \$30.2 million in 1952. Marketed value increased significantly from \$58.1 million in 1952 to \$66.3 million in 1953.

The high stock position at the beginning of the year caused considerable concern in the canned salmon industry. A U. K. purchase valued at \$4.25 million in March 1953, and increased U. S. purchases during the first six months of the year substantially reduced this carry-over before the major production season got under way. Prices offered to the fishermen at the start of the new season were lower than in 1952 despite union demands, but disagreements over prices did not materially affect fishing activities.

Salmon landings totalled 186.9 million pounds as against 142.9 million in 1952. Landings of pinks and chums exceeded expectations and sockeye landings showed an unexpected increase. Disappointing results in the northern areas throughout the season were more than offset by the very good landings in the southern areas.

The proportion of the catch that was canned increased from 61 percent in 1952 to 73 percent in 1953. The pack amounted to 1,825,000 cases, some 500,000 cases more than in 1952. Its market value, \$36 million, indicates its importance. The packs of sockeye and pinks were the largest for several years. Of the remainder of the catch, 14 percent was sold fresh and 12 percent was frozen.

Demand for canned salmon was good throughout the year, both at home and abroad, and prices improved somewhat toward the end of the season. Sales to the U. S. increased from \$3.15 million in 1952 to \$4.25 million in 1953, due in part to short domestic supply of canned fish in that country.

The outlook for the Canadian canned salmon industry in 1954 was definitely optimistic in tone. Negotiations between representatives of the industry and the U. K. government resulted in an agreement in February on a

"link purchase" plan whereby the U. K. would be provided with \$5 million for use in purchasing canned salmon during 1954. The Governments of Australia and New Zealand announced that dollars would be made available for imports of canned salmon valued at \$500,000 and \$600,000, respectively. The Italian Government also agreed, under an arrangement with the Canadian government, to provide dollars for imports of canned salmon valued at \$2 million during the year. The surplus stock problem no longer exists.

Contractual difficulties in the west coast herring industry which tied up the fleet throughout the 1952-53 winter season were settled in July and a good summer fishery ensued. The fall catch was of record proportions and boosted the year's production to 149.1 thousand tons, well above the 1952 level. Winter contract prices were higher than in the previous years and returns to the fishermen increased from \$3.2 million in 1952 to \$3.7 million in 1953. Supplies were excellent and quotas were extended in some areas. Most of the catch went to the reduction plants. The market for both meal and oil was depressed during November, but improved by the close of the year. Marketed value of 1953 production was \$6.5 million, 55 percent above the previous year, but well below all other post war years.

A record catch of halibut was landed, but low prices resulted in reduced returns to the fishermen. Results in the sole fishery were disappointing, and unsold stocks of frozen fillets from 1952 production depressed the market during 1953. Shellfish operations were extensive in the spring and landings of shrimp and crab showed notable increases.

Generally lower prices for fresh and frozen fish and an exceptionally mild winter played havoc with the freshwater fisheries. Mild weather during the 1952-53 winter season tied up transportation in remote areas and rendered customary storage facilities inoperative. Refrigerated transportation and storage facilities were insufficient to handle production and the resulting stock situation in the spring of 1953 necessitated government action. The Fisheries Prices Support Board was authorized to purchase a maximum of 3 million pounds of prairie lakefish most of which was channelled into meal production.

Total production during 1953 was an estimated 106 million pounds, about 3 million pounds more than in 1952. Landings of whitefish increased in most of the major fishing areas. Yellow pickerel was also taken in greater quantity. The catch of blue pickerel in the Great Lakes was substantially higher than in the previous year. Further declines in landings of lake trout in the Great Lakes were attributed to the lamprey menace. The catch of this species in Great Slave Lake was also smaller than in 1952. Prices were generally lower than in the previous year particularly for whitefish. Exports to the U. S. in filleted form were slightly higher in 1953 but exports in dressed and round form were lower. There was an increase in poundage exported, but lower prices resulted in a lower total export value than in the previous year.

COMMITTEE ON NAMES OF FISHES

REEVE M. BAILEY

In its continued deliberations this Committee has recognized the need for substantial increase in the number of fishes for which common names should be established. In anticipation of this undertaking, however, we note the need for a set of principles with which proposed common names can be assessed before adoption or rejection. The lack of any such code has in the past resulted in the admission of some names that are not the best available. We aim at the development of a body of names that reflect broad current usage, the creation of a richer, more meaningful and colorful vernacular nomenclature, and the promotion of mechanisms that will add to stability and the universality of names applied to American fishes.

The common name as here employed is viewed as a formal, anglicized appellation to be used in lieu of the Latinized scientific name of a species. It is hoped, and the history of the recent past confirms, that common names may be more stable than scientific names. Certainly they should be more readily adaptable to lay uses than scientific names. There is a clear need for standardization and uniformity in vernacular names not only for sport or commercial fishes, but as trade names, for aquarium fishes, in legal terminology, and as substitutes for scientific names of almost any fish in popular or scientific writing.

The Committee believes that it is desirable to establish a single common name for each species of fish occurring naturally or through successful introduction in the waters of English-speaking North America. In addition, certain exotic species that are of particular concern or interest in the area may be deemed worthy of placement on the list.

Agreement on many names may be arrived at quickly, but others are attended by complications and marked disagreement develops. This is especially true of fish known by market names as well as those that are more familiar to sport fishermen, biologists or others. The existence for a single species of different names in separate parts of its geographic range creates difficulties that seem soluble only through arbitration. Conversely a given name may be employed in several places for diverse species. Although committee action on such situations may not be expected to change local use quickly, at least it seems plainly improper to sanction use of one name for two or more different species (*e.g.*, skipjack for a herring and a bonito).

After wrestling with common names for over twenty years, the Committee on Names of Fishes realizes the importance of establishing a set of guiding principles to be employed in the determination of names. This should permit a more objective appraisal of the relative merits among several names than if selections are based primarily on personal experience and preference. Consideration of many vernacular names of fishes makes it apparent that few principles can be established for which some exceptions must not be admitted. This is true because at this late date a majority of our larger and more abundant, hence important, species have such firmly established common names that it would be wholly unrealistic to reject them. Decision on the name for a species may often be decided by weighing

the pros and cons among the possible alternatives and selecting that one which best fits the aggregate of guiding criteria.

In the introduction to the List of Names (1948, Am. Fish. Soc., Spec. Publ. 1) a number of rules of procedure were itemized. During the past year the Committee has incorporated these into the following statement of criteria that it regards as appropriate to the selection of common names of fishes. With this steering mechanism the Committee proposes to proceed with the task of expanding the list in anticipation of a revised second edition.

CRITERIA

1. *A single vernacular name shall be accepted for each species or taxonomic unit included.*—At present only three fishes on the list have two approved names: California sardine and pilchard for *Sardinops caerulea*; steelhead and rainbow trout for *Salmo gairdneri*; and Atlantic salmon and lake Atlantic salmon for *Salmo salar*.

2. *No two species on the list shall have the same approved name.*

3. *The expression "common" in connection with a fish's name shall be avoided wherever possible.*

4. *Simplicity in names is favored.*—Hyphens, suffixes, and apostrophes shall be omitted (e.g., smallmouth bass) except where they are orthographically essential, have a special meaning (e.g., C-O flounder), or are necessary to avoid possible misunderstanding (e.g., trout-perch). Compounded modifying words, including paired structures, should usually be treated as singular nouns in apposition with a group name (e.g., spottail shiner, soupfin shark), but a plural modifier should usually be placed in adjectival form (e.g., blackbanded sunfish, spotted jewfish). Preference shall be given to names which are short and euphonious.

The compounding of brief, familiar words into a single name, written without hyphen, may in some cases promote clarity and simplicity (e.g., tomcod, goldfish, mudminnow), but the wholesale practice of combining words, especially those that are lengthy, awkward, or unfamiliar, is deplored.

5. *Common names shall not be capitalized in text use except for those elements that are proper names* (e.g., rainbow trout but Sacramento perch).

6. *Names intended to honor persons* (e.g., Allison's tuna, Julia's darter) *are not admissible.*

7. *Only clearly defined and well-marked taxonomic entities* (usually species) *shall be assigned common names.*—Most subspecies are not suitable subjects for common names, but those forms that are so different in appearance (not just in geographic distribution) as to be distinguished readily by sport or commercial fishermen or laymen or for which a common name constitutes a significant aid in communication may merit separate names. Subspecies have importance in evolutionary inquiry but are rarely of significance to laymen or in those aspects of biological endeavor in which common names are of concern. The practice of adding geographic modifiers to designate regional populations makes for a cumbersome terminology.

8. *The common name shall not be intimately tied to the scientific*

name.—Thus the vagaries of scientific nomenclature do not entail constant changing of common names. The practice of applying one name to each genus, a modifying name for each species, and still another modifier for each subspecies, while appealing in its simplicity, has the defect of inflexibility. If a fish is transferred from genus to genus, or shifted from species to subspecies or vice versa, the common name should nevertheless remain unaffected. It is not a primary function of common names to indicate relationship. When two or more taxonomic groups (*e.g.*, nominal species) are found to be identical, one name shall be adopted for the combined group.

This principle is regarded not only as fundamental to the achievement of stability, but as essential to the development of a true vernacular nomenclature.

9. *Names shall not violate the tenets of good taste.*

The preceding principles are largely in the nature of procedural dicta. Those given below are criteria which are regarded as aids in the selection of suitable names.

10. *Colorful, romantic, fanciful, metaphorical, and otherwise distinctive and original names are especially appropriate.*—Such terminology adds to the richness and breadth of the nomenclature and yields a harvest of satisfaction to the user. Examples of such names include: Dolly Varden, madtom, hogchoker, garibaldi, pumpkinseed, flier, angelfish, midshipman, and chili-pepper.

11. *Amerindian names are welcome for adoption as common names.*—Those in current use include muskellunge, eulachon, mummichog, chinook, squeteague, tautog, menhaden, and cisco.

12. *Regardless of origin, truly vernacular names that are widespread and in common use by the public are to be retained wherever possible.*—In addition to aboriginal names, many now well-known names of American fishes have been derived from non-English-speaking fishermen of foreign extraction: barracuda, cero, grouper, pompano (Spanish); bocaccio (Italian); capelin, inconnu (French). Although too little genuine originality is evident, many excellent names have been developed by American immigrants. Most of these conform to principles 14 and 15 below.

13. *Commonly employed names adopted from traditional English usage (*e.g.*, cod, pike, sole, flounder, bass, perch, chub, minnow) may be given considerable latitude in taxonomic placement.*—Adherence to customary English practice is to be preferred if this does not conflict with the broad general use of another name. Many English names, however, have been applied to similar appearing but often distantly related fishes in America. We find perch in use for representatives of at least 9 families of spiny-rayed fishes. Chub appears in such diverse groups as the Salmonidae, Cyprinidae, and Kyphosidae. The ocean whitefish (*Caulolatilus princeps*) is not a salmonoid and the blue pike (*Stizostedion vitreum glaucum*) is remote from the Esocidae, yet each is best known to fishermen throughout its range by the name indicated. For widely-known species the Committee believes it preferable to recognize general use than to engage in a probably futile effort to gain the general adoption of bookish or pedantic substitutes.

Thus, established practice should outweigh consistency with original English usage.

14. *Structural attributes, including color and color pattern, are desirable and are in common use in forming names.*—Sailfin, flathead, slippery, giant, mottled, copper, tripletail, and a multitude of others decorate fish names. Efforts should be made to select terms which are descriptively accurate, and to hold to a minimum repetition of those most frequently employed (e.g., white, black, spotted, banded).

15. *Ecological characteristics are useful in making good names.*—They too should be properly descriptive. Terms such as sand, rock, lake, riffle, freshwater, and mountain are well known in fish names.

16. *Geographic distribution provides as suitable adjectival modifiers as do morphology and habitat.*—Poorly descriptive or misleading geographic characterizations (e.g., Kentucky bass for a wide-ranging species) should be corrected unless they are too deeply entrenched in current usage. In the interest of brevity it is usually possible to delete words such as lake, river, or ocean in the names of species (e.g., Colorado squawfish, not Colorado River squawfish).

17. *Generic names may be employed outright (e.g., gambusia) or in modified form (e.g., molly, from Mollienesia) as common names.* Once adopted such names should be maintained even if the generic name is changed. These vernaculars should be written in Roman and without capitalization. Brevity and euphony are of especial importance for names of this type, which will probably be adopted most often for aquarium fishes or other smaller and little-known kinds that do not already have a well-established vernacular nomenclature.

18. *The duplication of common names for fishes and other organisms should be avoided where possible, but names in wide general use need not be rejected on this basis alone.*—The name dolphin is commonly applied to certain cetaceans and also to *Coryphaena hippurus*. Similarly, buffalo is employed for various artiodactyls and for suckers of the genus *Ictiobus*. On the basis of prevailing use these names are admissible as fish names.

19. *Names that appear on official lists of names of fishes prepared by other agencies shall be preferred.*

EMENDATIONS TO THE LIST OF COMMON NAMES

For some time the Committee has been investigating a number of names on the list for which changes have been requested. Three emendations and one addition are now recommended by the Committee.

DOLPHIN shall replace DORADO for *Coryphaena hippurus* (number 339 on the List of Names). The related species, *Coryphaena equisetis*, may be added to the list with the name LITTLE DOLPHIN.

SKIPJACK HERRING shall replace SKIPJACK for *Alosa* (or *Pomolobus*) *chrysochloris* (number 91 on List of Names).

OCEAN PERCH shall replace ROSEFISH for *Sebastes marinus* (number 474 on List of Names). The Committee makes this recommendation with reluctance, and does so simply because of the wide use of ocean perch as a market name. We do not regard this name as a happy choice.

REPORTS OF SPECIAL COMMITTEES

COMMITTEE ON WATER POLLUTION

PETER DOUDOROFF

The primary duty of this committee was to arrive at a final decision regarding the most desirable future activities, function, and status of a committee on water pollution in the American Fisheries Society, and to make appropriate recommendations to the Society. The committee's functions had been discussed in the committee report presented at the 1953 meeting of the Society, but no decision had been reached at that time. After some additional correspondence, it was agreed that the following specific recommendations should be reported to the Society:

1. If the Committee on Water Pollution is to continue functioning, it should be established as a Standing Committee by amendment of the By-laws. It should be noted in this connection that there has been a Special Committee on pollution in the Society during each of the past 20 years, excepting the year 1949-1950. A resolution to the effect that an amendment to the By-laws be instigated to place the Special Committee on a permanent standing basis was proposed by the Resolutions Committee at the 1950 meeting, and apparently was adopted by the Society at that meeting (see TRANSACTIONS, Vol. 80, p. 364, Resolution No. 7), but has not yet been carried out. Inasmuch as there is evidently a recognized, continuing need for the services of such a committee, and its work obviously can be carried out best on a sustained basis, without annual interruptions which are involved in the reactivation of Special Committees, an amendment of the By-laws creating and defining the functions of a Standing Committee on Water Pollution is again recommended.

2. The chief function of a Standing Committee on Water Pollution should be to keep the society informed about major developments in the fields of water pollution research relating to fish and fisheries and of water pollution abatement, including pertinent legislation. The committee should maintain a continuous survey and appraisal of both research and applied work in the water pollution field, relieving the Committee on Hydrobiology and Fish Culture of responsibility in this connection; and it should report its findings annually to the Society, including in its reports such recommendations for action by the Society as may be considered appropriate.

In this way, the committee can keep Society members informed about fishery research and related activities of which they too often are not aware, because much of the work on pollution problems is carried on by organizations and agencies which are not engaged primarily in fishery research and management, and the results often are reported in publications which are not ordinarily consulted by fishery scientists. Unnecessary duplication of effort, which has occurred often in the past, thus can be mini-

mized. The committee can bring to the attention of Society members also major pollution problems involving fisheries, and steps taken toward their solution, including the development of promising new waste disposal techniques, as well as the need for remedial action where none is forthcoming. By recommending appropriate resolutions for adoption by the Society, it can help to promote needed pollution control legislation or administrative action. Adequate consideration for fisheries interests in the development of pollution control and research programs by responsible governmental agencies, which too often have not given sufficient attention in the past to the fisheries conservation aspects of water pollution control, thus can be promoted.

3. The standing committee should consist of at least seven, and preferably ten, members in good standing, representing different regions of North America and familiar with water pollution control activities and problems and related research in their regions. It has been suggested that it may be desirable for the Society to request the formation of regional sub-committees on water pollution by the several regional divisions of the Society, which could work with, and report to, the Standing Committee. The chairman of each regional sub-committee could be appointed a member of the standing committee, and could funnel to its chairman all pertinent information collected in his region by members of his sub-committee, assuming some of the responsibility for the proper evaluation and organization of material to be included in committee reports. Thus, some of the advantages of having both a large and a relatively small committee could be realized. It may be desirable for the Society to request the appointment of the regional sub-committees in advance of the establishment of the Standing Committee, in anticipation of their proposed integration.

In addition to consideration of the matters discussed above, a preliminary survey of recent and current research in the effects of water pollution on fish and fisheries has been undertaken, with a view to eventual preparation and maintenance of a reasonably complete inventory of the research projects and related activities. Available compendia of pertinent information, such as the "Survey of Sport Fishery Projects, 1954" prepared by the U. S. Fish and Wildlife Service, were helpful, but are not sufficiently complete or comparable in scope to the proposed inventory. A survey of recent literature revealed significant trends in current research, and where productive work has been done heretofore. It will be necessary, however, to circularize all organizations and persons likely to be actively engaged in pertinent research before the planned inventory can be completed. Time did not permit such an undertaking, but it is hoped that a Standing Committee will continue the survey which has been initiated. Only a few notes and news of general interest concerning current research activities are included in this report.

There is evidence of growing interest in the toxicology of aquatic organisms, an increasing recognition of the value of toxicity bioassays of industrial wastes, in connection with the control of industrial waste disposal. Recommendations directed toward standardization of bioassay

methods, involving the use of fish as test animals, have been published in 1951 by a qualified committee in the Federation of Sewage and Industrial Wastes Associations, representing a variety of viewpoints and interests; and they are being adopted and endorsed by other influential organizations. Intensive literature research in fish toxicology has led to the publication of several comprehensive literature reviews and compendia. Experimental investigations of the toxicity of industrial wastes to aquatic organizations are being carried on or supported by several industrial concerns and organizations (notably the pulp and paper, the petroleum, and some chemical industries) as well as government agencies and academic institutions. States in which laboratories for such studies have been maintained for some time or are now being established by State regulatory agencies concerned with water pollution are New York, Pennsylvania, Washington, Louisiana, Ohio, probably Maryland, and perhaps others. In New York, the toxicity of copper, cyanide, cupro-cyanides and rotenone, and methods of post-mortem determination of the cyanide content of fish are now under investigation by the Division of Fish and Game. In Washington, important studies of the toxicity of pulp-mill wastes to anadromous fishes and food organisms have been conducted jointly by the Department of Fisheries and the Pollution Control Commission.

A notable development of the past year has been the establishment of a joint program of intensified research and graduate instruction in fish toxicology and physiology relating to water pollution, and in other phases of water pollution biology, by the Department of Fish and Game Management of Oregon State College and the Robert A. Taft Sanitary Engineering Center (formerly the Environmental Health Center) of the U. S. Public Health Service. In November of 1953, the Toxicity and Fisheries Unit of the Center's Biology Section was transferred from Cincinnati, Ohio, to Corvallis, Oregon, for the purpose of integration of its research program with the corresponding program of Oregon State College. Laboratory space has been provided by the College in Corvallis, with additional facilities on Yaquina Bay near Newport, Oregon, and both of the cooperating organizations contribute laboratory personnel, equipment and supplies. Graduate students have the opportunity to work under the direction of the Federal collaborators, who have appropriate academic status. Cooperative relations exist with several departments of the College, with State agencies, and with the National Council for Stream Improvement of the Pulp and Paper Industry, whose grants to the College contribute to the maintenance of research fellowships. Current investigations include studies of the influence of variations of dissolved oxygen concentration upon the survival, food consumption, growth and activity potential of fishes; the nature, relative toxicity, and interactions of the important constituents of some complex industrial wastes which are toxic to fish; and avoidance reactions of fishes to water pollutants.

Other related studies are still carried on at the Sanitary Engineering Center in Cincinnati and are supported by Public Health Service research grants to other institutions. The U. S. Fish and Wildlife Service also has

been engaged in some investigations of the toxicity of various chemicals to fish, but mostly without particular reference to water pollution. Its participation in water pollution research has been very limited in recent years, since the enactment of the Federal Water Pollution Control Act in 1948. Thus, despite increased Federal appropriations for water pollution investigations in general, and the fact that the Public Health Service has greatly expanded its program of fisheries research relating to water pollution, in accordance with the recent legislation, it cannot be said that the over-all Federal activity in the field of research under consideration is unprecedented. On the contrary, it appears that there has been a considerable reduction of Federal personnel and facilities devoted to such research since the time when the Fish and Wildlife Service was most actively engaged therein.

Generally speaking, basic research in the effects of water pollutants on aquatic life has not kept pace with the rapidly growing need for reliable basic data, associated with continued growth and diversification of industry and increasingly urgent demands for effective pollution control. While some industries and State agencies concerned with pollution abatement have been making important contributions, too many others have been notably indifferent to the need for basic biological research. Observations made in the course of superficial water pollution surveys, which have been reported frequently, are not often very instructive. Broader participation in research which is essential as a basis for sound interpretation of these observations should be encouraged in every possible way.

DR. DOUDOROFF: I move that the By-laws of the American Fisheries Society be amended to create and define the duties of a Standing Committee on Water Pollution. The chief function of this committee shall be to keep the Society informed of major developments in the fields of water pollution research relating to fish and fisheries, including protective legislation and shall consist of not less than seven or more than ten members, recognized specialists in water pollution fields and familiar with water pollution problems in different regions in North America.

PRESIDENT THOMPSON: Gentlemen; you have the report and also a motion for the amendment of the By-laws to establish a Committee on Water Pollution as a Standing Committee. [The motion was seconded.]

MR. SPRECHER: This is a rather complicated issue and I wonder if the members of the Society understand just what the ramifications are of the creation of such a committee. It seems to me that the amendment should be studied by the Executive Committee and brought up again at a later date.

DR. HILE: I concur with Mr. Sprecher, that the idea is excellent but I do think it needs to be smoothed out a bit. I am sure that some of the members would like to do a little penciling on portions of it to make it fit into the By-laws.

PRESIDENT THOMPSON: The motion to be acted upon and if passed as amended now, is that it be referred to the Executive Committee for smoothing out and balancing with the rest of the By-laws. [Motion as amended was seconded and carried.]

MR. JAMES: I would like to make the further motion that at the earliest convenience of the new President the Standing Committee be appointed in order that it may get functioning. [Motion was seconded and carried.]

COMMITTEE ON THE IMPORTATION OF FISH AND FISH EGGS

O. LLOYD MEEHEAN

Many states and commercial trout hatcheries purchase eggs from commercial sources, or obtain them from other states or from Provinces of Canada. These may or may not originate in the hatchery from which they are obtained, and at times may actually be of foreign origin. It is known that some dealers obtain eggs from sources outside the country. There are no readily available data on the total amount of imports because the information is combined with similar products in the customs reports. Attaché reports indicate that imports of live pond trout from Denmark in 1952 totalled 4.3 tons, and in 1953 dropped to 0.1 ton. The statement is made that this is trout brood, (presumably eggs). Other possible sources of eggs of foreign origin would include Greenland, Iceland, Canada, and Japan. It would require some expense to have an analysis made of the customs data, and the cost is not believed justified at this time.

Many new diseases have been identified or recognized in the last few years. Regardless of whether these may have been present, but unrecognized, in the past or are new with origin unknown, the fact remains that we have definite evidence that diseases can be transmitted with eggs, live fish, containers, equipment, and water. For example, there has been a spread of kidney disease from an area centering in the vicinity of Massachusetts to all of New England and certain hatcheries in the Midwest and West. It is, primarily, a disease of brook trout, and was probably spread through shipments originating in the East. Instances have been reported, in both commercial and government hatcheries, of disease outbreaks following the transfer of eggs, fish, or equipment.

Recently, virus diseases have come to the fore in the attention of fish pathologists. Although there are records of their transmittal within the egg, we have no information regarding the seriousness of the problem. The virus infection among sockeye salmon in the Northwest is virulent enough to eradicate whole hatchery stocks. Sterilization would not alleviate this situation if the disease were transmitted within the cell. Our knowledge of this method of transmittal is not sufficient to make recommendations regarding parent stock at this time.

Therefore, the Committee recommends that ports of entry be established and that, to control disease, all eggs of salmonid species be sterilized according to good prophylactic methods along with containers and any equipment; and suggests that a committee be established to take such steps as are necessary to implement (1) the recommendation that ports of entry be established and (2) define the techniques by which all eggs from all Salmonidae entering or leaving this country be sterilized along with containers and equipment.

Along with this problem is the one involving transmittal of diseases through aquarium species imported into this country. Many of these are contaminated with infectious diseases and parasites. Correspondence with the industry reveals that a number of new diseases have been found in

recent years. Again, these may or may not have been brought in from other countries or may have been present but unrecognized. With the present state of our knowledge, a quarantine of these species is not the answer to the problem of disease or parasite control since, even after a period of as long as a month, outbreaks are known to occur. Until more is known regarding control methods, no practical solution is available. If we are to increase our knowledge in this field and accomplish control measures, we should know more of the magnitude of the problem, the sources of supply, the destination, and species of fish involved.

A third problem concerns importation of fishes for stocking, rearing, or bait purposes. Many conservation agencies receive requests from individuals in foreign countries for information on obtaining various species of fish and eggs for stocking purposes from the United States. Likewise, we have reason to believe, based on inquiries coming to the Fish and Wildlife Service, that Americans have interest from time to time in species of foreign origin. For example, the most recent one of widespread interest is the propagation of *Tilapia*.

A number of states have laws requiring permits for stocking exotic species, or even for the importation of fish from outside state boundaries. The majority do not have adequate machinery for enforcement of such regulations. Most states have some policy or regulations on stocking fishes from hatcheries in public waters but here, too, clubs and organizations may contaminate a watershed with species not suited to the environment by importation without approval of the state conservation department. A recent example is the importation of minnows for bait purposes through the port of New Orleans. It is conceivable that without some control measures we could have another carp, or English sparrow, or starling problem on our hands.

Therefore, the Committee recommends that a committee be established to study the extent of importation of live fishes, the seriousness of the disease problem, the magnitude of importation for bait or stocking purposes, and the methods of approach to a solution of the problems resulting from these importations.

COMMITTEE ON THE NORTH AMERICAN FISH POLICY¹

ALBERT S. HAZZARD

To strengthen the purposes and to achieve the objectives of the American Fisheries Society, the following policy is adopted:

I. STATE, NATIONAL, AND INTERNATIONAL RELATIONS

The individual States should be responsible for the administration and management of the fisheries within their respective boundaries and should perform, by agreements, these functions for interstate fisheries.

¹ A revision of the North American Fish Policy which was adopted by the Society in 1938 and published in the Transactions of the American Fisheries Society, Vol. 68 (1938), pp. 40-51.

The Federal Governments, in addition to fulfilling their responsibilities for the administration of laws pertaining to national, territorial, and international fisheries, should collect and disseminate information on fisheries and should serve in an advisory capacity to the States and Provinces on fishery problems.

Where two or more nations share a fishery, rational management should be secured by means of a multilateral approach and international agreement. In promulgating these treaties the signatory nations should take into account the research and conservation measures undertaken by the component States and Provinces.

II. ADMINISTRATION OF FISHERIES

Fisheries should be administered on a nonpolitical basis and by individuals trained and experienced in the scientific management of fisheries. Biological facts should receive primary consideration in the utilization of fish stocks. The agency charged with the administration of the fisheries should be responsible for establishing needed regulations.

Public access to sport fisheries is of paramount importance. Present public ownership of water frontage should be jealously guarded and should be expanded at every opportunity.

Conflicts between sport and commercial fisheries should be settled on the pertinent facts in each case. In many instances waters will support both types of fisheries with mutual benefit. Where actual competition exists to the proven detriment of either fishery, an objective economic appraisal should form the basis for the determination of proper regulations.

III. RESEARCH

The success of any fish-management policy, in private or in public waters, is in proportion to its basis on factual information. This is a clear demonstration of the prior requirement for research in all phases of fish management.

The necessary research, conducted by trained personnel, must range from detailed physiological studies on individual fishes to broad-scale studies of the relationships of populations and environmental conditions.

Constructive programs of research should be developed by universities and by administrative units—State, Provincial, or Federal—to make the most advantageous use of available facilities and personnel. The comprehensive programs made possible through such coordination of resources should encompass the necessary fundamental research in all related fields and the practical problems arising from the application of research findings.

IV. MANAGEMENT

Regulatory laws, stocking, and habitat improvement are the presently recognized tools for management of most sport and commercial fisheries.

Laws for regulation of the catch should be based upon proved need,

limited to those necessary for orderly management of fish stocks, and stated as simply as possible. The harvestable surplus of fish should be removed at the most desirable size and in the best condition for sport and food.

Food, game, and forage fishes reared at public expense should be stocked only for public benefit; private fish culture should be encouraged to supply privately owned waters. Only fish free of objectionable diseases and parasites should be used for stocking. Periodic replanting is desirable of lakes that winterkill infrequently or of waters which are occasionally depleted by pollution; otherwise the stocking of the young of any species in waters having adequate spawning conditions is considered of doubtful value. The introduction of exotic species is proper where adequate biological investigation has demonstrated the need and the suitability of the environment including the possible effects on contiguous waters.

Planting catchable fish in waters where reproduction is lacking and where environmental deficiencies cannot be remedied, is recommended if those who benefit pay the cost of such stocking. Elsewhere public agencies should limit the harvest to the extent that good sport will be maintained by natural spawning. In heavily used waters, fishing for game species must be regarded as a source of recreation, not meat. Private fish culture should be encouraged to provide fish for the table and for those who must have, and will pay for, a full creel.

Habitat improvement includes creation of new fishing waters, control of pollution including soil erosion, and provision of additional shelter, food, and spawning facilities for fish. Such work should be preceded by a physical and biological survey to determine the factors limiting fish production and the remedies to be applied. The watershed approach is recognized as logical and most efficient.

V. MULTIPLE USE OF WATERS

Fishery resources are too important to be disregarded in any water-development project. Throughout most of North America the scarcity of water precludes any single-purpose development. Any plan to use water for power, irrigation, navigation, mining or to carry waste products should include maintenance of the fisheries as a co-equal objective and become part of the project cost.

Wherever an agency plans any development that will impair either the quantity or the quality of water available for fish life, mitigation of fish losses should be the financial responsibility of the sponsoring agency. Local projects are State or Provincial responsibilities. Interstate problems should be solved by interstate compacts.

The Federal agencies concerned with fisheries and public health should be responsible for conducting research in cooperation with the States and Provinces on the effects of pollution and other water uses and on methods for preventing loss of fish. State and Provincial agencies should conduct research on purely local problems.

VI. ADOPTION OF UNIFORM COMMON AND SCIENTIFIC NAMES OF FISHES

The standing committee of the Society should accelerate its efforts to have the most appropriate common names accepted by fishery administrators and the general public.

VII. EDUCATION AND PUBLICITY

Progress in management of fisheries is dependent upon public understanding and acceptance of current and proposed programs. Every available means should be employed to disseminate factual information in a form that will be readily understood and accepted.

REPORTS OF SESSIONAL COMMITTEES

COMMITTEE ON TIME AND PLACE

RALPH HILE

For some years we have felt the need to schedule the meetings of the American Fisheries Society more than 1 year in advance. The growing number of conventions, the tightness of hotel bookings, and the difficulty of making local arrangements for the entertainment of the increasing numbers attending our Annual Meetings combined to make necessary the amendment to our By-laws under which this Committee is submitting recommendations on the time and place for both our 1955 and 1956 meetings.

It is recommended that the American Fisheries Society meet in Augusta, Georgia, September 14-16, 1955, and in Toronto, Ontario, September 10-12, 1956.

AUDITING COMMITTEE

H. H. MacKay

The Auditing Committee has examined the accounts of the American Fisheries Society for the fiscal year 1953-1954 and has found them to be correct. The Committee wishes to commend the Secretary-Treasurer and his assistants for the meticulous manner in which the accounts and records of the Society have been handled.

RESOLUTIONS COMMITTEE

MILTON C. JAMES

1. Great Lakes Fisheries Treaty

WHEREAS, Long years of discussion and negotiations have at last culminated in the signing by the United States and Canada of a Convention designed to overcome the difficulty of multiple and international jurisdiction over the fisheries of the Great Lakes, and

WHEREAS, The pattern for cooperative joint research and investigation embodied in this Convention has in the case of other Fishery Conventions lead to worthwhile and lasting benefits,

THEREFORE BE IT RESOLVED, That the American Fisheries Society registers its satisfaction and gratification at the successful outcome of an effort

which the Society has endorsed in the past, and the Society further urges that the United States Government and the Canadian Government proceed immediately and expeditiously to undertake those steps leading toward early legislative ratification of the document in order that it may enter into force at the earliest possible date.

2. Multiple Use of Waters

WHEREAS, The problem of multiple use development of waters in river basins has direct impact upon fisheries, and

WHEREAS, Present day engineering projects are developing at an increased tempo resulting in greater destruction of fish, and

WHEREAS, Such destruction may be minimized if proper technical knowledge is immediately brought to the solution of the problem, and

WHEREAS, Such destruction has a tremendous impact on both our commercial and sport fisheries as exemplified on the Columbia River,

THEREFORE BE IT RESOLVED, That the American Fisheries Society urges that fishery problems in any river basin be considered in the light of the entire watershed affected and that fishery aspects be given full consideration during all planning stages concurrently with power, irrigation, navigation, mining or other purposes.

3. Dingell-Johnson Program

WHEREAS, Criticism is being directed against the principle of Federal Aid to the States in various fields of governmental functions, and

WHEREAS, The American Fisheries Society is not qualified to express an opinion as to the desirability of Federal Aid to the States as a broad national policy, and

WHEREAS, The American Fisheries Society is in a position to appraise the value of such a program in the field of fish management and conservation as typified by the Dingell-Johnson program,

THEREFORE BE IT RESOLVED, That the American Fisheries Society go on record as expressing its belief that the Federal Aid to fisheries program as authorized by the Dingell-Johnson Act is a useful and beneficial measure which should be judged on its own merits without regard to the status of other types of Federal Aid Programs.

4. Thanks to Program Committee

WHEREAS, The American Fisheries Society has carried on its 84th annual meeting in an atmosphere of cordial welcome, true hospitality and helpful cooperation, and

WHEREAS, The officers and staff of the Washington Department of Game and of the Washington Department of Fisheries have exerted unceasing effort to bringing this about.

THEREFORE BE IT RESOLVED, That the American Fisheries Society hereby express its sincere thanks and appreciation for this courtesy to the

agencies named above, to Mr. Clarence Pautzke, Chairman of the Program Committee and to those civic groups and those business firms whose contributions are acknowledged in the official program.

PROPOSAL FOR AMENDMENT OF THE CONSTITUTION

[The following proposal to amend Article IV, Paragraph 4, of the Constitution was signed by 50 members in good standing, circulated by the Secretary, and referred to the Resolutions Committee for presentation at the concluding business session. The proposal was defeated by a standing vote. Following defeat of the proposal, a motion was adopted instructing the new President to appoint a Special Committee to arrange for the consideration of a similar proposal at the next Annual Meeting.]

Election of officers shall be by ballot distributed to all active members in good standing, life members, and distinguished service honorary members, and election shall be by a majority of those voting. In the event of a tie in the ballot vote for any officer, the choice shall be made by a majority of the members in good standing in attendance at the session at which the results of the balloting are announced. Decisions at meetings, including election of new members and of non-appointive standing committees, shall be by majority of the members in good standing present at any meeting; *except that* a two-thirds majority shall be required for a motion for amendment of By-laws adopted pursuant to Article V; and *excepted further that* a three-quarter majority shall be required for the election of distinguished service honorary members.

NOMINATING COMMITTEE

GEORGE E. BUTLER

I would like to preface this report by thanking the members of the committee who helped to make this report possible. Nominations have been made with due regard to geography, ability and the different organizations which parties may represent. With your permission I shall read down the list.

OFFICERS

<i>President</i>	A. L. Pritchard, Ontario
<i>First Vice-President</i>	G. E. Sprecher, Wisconsin
<i>Second Vice-President</i>	O. L. Meehan, Washington, D.C.
<i>Secretary-Treasurer</i>	E. B. Speaker, Iowa
<i>Librarian</i>	Howard A. Tanner, Colorado

COMMITTEE ON INTERNATIONAL RELATIONS

William R. Martin, New Brunswick, *Chairman* -
Jose L. Cardona-Cooper, Costa Rica
Richard Croker, California
James W. Moffett, Michigan
Alfred W. H. Needler, British Columbia
Paul E. Thompson, District of Columbia
W. H. R. Werner, Ontario

COMMITTEE ON NATIONAL-STATE RELATIONS

Alexander J. Calhoun, California, *Chairman*
Robert S. Campbell, Missouri
James H. Cornell, North Carolina
Raymond E. Johnson, Minnesota
Willis King, Georgia

COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

Richard B. Miller, Alberta, *Chairman*
Paul H. Eschmeyer, Michigan
Robert G. Ferguson, Ontario
Clarence F. Pautzke, Washington
Stanislas F. Snieszko, West Virginia
Gerry Wade, Maine
Richard A. Wagner, Washington

COMMITTEE ON COMMERCIAL FISHERIES

Albert L. Tester, Hawaii, *Chairman*
William W. Anderson, Georgia
Harold F. Cary, California
Milton C. James, Washington
Lee S. Roach, Ohio
A. H. Underhill, New Jersey
Claude Ver Duin, Michigan

COMMITTEE ON NAMES OF FISHES

Reeve M. Bailey, Michigan, *Chairman*
Ernest A. Lachner, District of Columbia
Edward C. Raney, New York
William E. Ricker, British Columbia
William B. Scott, Ontario
Royal D. Suttkus, Louisiana
Loran P. Woods, Illinois

PRESIDENT THOMPSON: If there are no nominations from the floor on the Standing Committees we will vote on them in a group to save time. Then we will take the officers one by one, allowing time for nominations from the floor. If there are no other nominations for Librarian, we will consider Howard Tanner as nominated by acclamation. Any nominations from the floor for Secretary-Treasurer? [No response.] For Second Vice-President, O. Lloyd Meehan. Any nominations from the floor?

MR. REID: I nominate Clarence Pautzke.

PRESIDENT THOMPSON: Clarence Pautzke has been nominated as Second Vice-President. It has been moved and seconded that the nominations be closed. We will have a paper ballot on this one, I believe that is the only reasonable way to do it although it will take a little time. It has been suggested from the floor that we have a standing ballot. [Standing ballot was taken.] The vote stands at 40 for Dr. Meehan and 60 for Clarence Pautzke.

DR. MEEHEAN: I would like to withdraw my name from the ballot and have the Chair declare an unanimous ballot for Clarence Pautzke.

PRESIDENT THOMPSON: Dr. Meehan has requested that his name be withdrawn from the ticket and that Clarence Pautzke be elected by unanimous acclamation. Is there a second to the motion? [The motion was seconded and carried.] For First Vice-President we have George Sprecher. Are there any nominations from the floor? [No response.] Mr. Sprecher is elected First Vice-President. Are there any further nominations for President? [No response.] Mr. Pritchard is elected as President of the American Fisheries Society for the ensuing year. [Applause.]

PRESIDENT THOMPSON: I would like to ask Dr. Harkness to escort the honorable President to the rostrum. Dr. Pritchard, I hope that you may receive as good cooperation from this group as I have because I certainly think it is a wonderful outfit.

PRESIDENT-ELECT PRITCHARD: Gentlemen, fellow members of the American Fisheries Society; I had a two-hour speech prepared to accept this signal honor which you have conferred upon me but I realized suddenly while sitting in the back of the room with some of my compatriots that I can't compete with the hospitality that has been handed out to us by the Washington State Fisheries Department.

I would like to say, however, that I deeply appreciate the honor which you have conferred upon me personally in selecting me as President of the Society for this year. I realize, in the main, you are honoring the country and the organization which I represent. I will try to do my very best to carry on in the able way in which your preceding president has done.

I feel sure that with the executives you have elected, I will not be allowed to make many mistakes. It may be that I will be stimulated into starting a lot of arguments but that would suit me very well with my Irish ancestry. [Applause.]

PRESIDENT PRITCHARD: Is there any other business to come before this meetings?

DR. MEEHEAN: I presented yesterday morning, a report of the Committee on Importation of Fish and Fish Eggs in which two recommendations were made. A committee was established to take such steps as are necessary to implement the recommendation that ports of entry be established and to define techniques by which eggs from all Salmonidae entering or leaving this country shall be sterilized along with the containers.

PRESIDENT PRITCHARD: Now, if we are to understand the motion fully, you are proposing that a committee be established to look into the matter of ports of entry for the importation of fish and fish eggs and that all Salmonidae eggs and containers being shipped into and out of the country should be sterilized. Is there any discussion?

MR. CORNELL: Does that pertain only to Salmonidae, Dr. Meehean, or anything else?

DR. MEEHEAN: No, just to Salmonidae. I have explored the problem with a number of people and found it would be rather impracticable to do it with other species at this time.

PRESIDENT PRITCHARD: With that explanation is there any further discussion? [Motion passed.]

DR. MEEHEAN: Perhaps I ought to give a little explanation in regard to the second recommendation of the committee. In considering the problem we found that aquarium species and other species could be imported or exported from this country without restriction.

In talking with people concerned with the matter, they recommended that something should be done. The committee first considered the possibility of suggesting that a permit system be established for the importing or exporting of fish simply as a means of finding out the magnitude of the problem to control shipments of fish into states that have laws governing that sort of thing and as a method of at some later date implementing the procedures whereby we can control diseases and parasite problems.

After discussing it at considerable length we found it would be a rather difficult thing to do but it should be given some study and the magnitude of the problem should be determined.

The Committee has therefore recommended that a committee be established to study the extent of importation of live fishes, the seriousness of the disease problem,

the magnitude of importation for bait and stocking purposes and the methods of approach to a solution of the problem resulting from these importations.

I move that such a committee be established.

PRESIDENT PRITCHARD: Seconded by Mr. Wagner of Arizona. You have heard the motion. Are you ready for the question? [Motion carried.]

PRESIDENT PRITCHARD: Is there any further business to bring before this meeting?

DR. ROUNSEFELL: I make a motion that the name of the Society be changed from the American Fisheries Society to the North American Fisheries Society.

PRESIDENT PRITCHARD: It has been duly moved and seconded that such a change take place. This, of course, will not take place until next year and it will be considered then. It has to be circulated and will come up for further discussion. Is there any further discussion.

DR. HAZZARD: I wonder if we want to bar the countries in Central America and South America who might join with us. We would be doing so by labeling our Society the North American Fisheries Society.

PRESIDENT PRITCHARD: Any further discussion? [Motion put to vote and failed.]

PRESIDENT PRITCHARD: Any further business?

MR HUTCHINSON: Mr. President, in the fading moments of this business meeting, I would like to make the further motion that we all stand and give a rising vote of appreciation to our past president, Mr. Thompson. [Applause.]

PRESIDENT PRITCHARD: The meeting is now adjourned.

Appendices

(REVISED 1954)

Please check each item below before the final typing of your manuscript and help reduce the costs of publication, save your Editorial Board much needless work, and avoid delay in the publication of the *Transactions*.

The following instructions were not drawn up arbitrarily but were condensed from the regulations contained in the best style manuals. Certain instructions may appear unnecessary, but they are nevertheless essential for the proper handling of materials by the printer and the editor.

I. MECHANICAL DETAILS

1. **Manuscript must be typewritten double-spaced**, including titles, headings, legends for tables and illustrations, and literature citations. Write manuscript only in simple upper and lower case. *Do not use all capital letters for any purpose and underscore only where italics are intended.*

2. **Carbon copies or originals made with a worn-out ribbon will not be accepted.** Do not use thin paper; heavy bond is preferred.

3. **Margins** at top, bottom, and both sides must be no less than $1\frac{1}{4}$ inches to allow space for the insertion of directions to the printer and necessary corrections.

4. **Pages must be numbered in consecutive order**, including tables and pages carrying legends to figures. Tables and legends of figures must be inserted near their place of reference in the text.

5. **Illustrations.** Make a separate page of each figure legend and limit the number of figures to those absolutely necessary to clarify or supplement text. Only sharp, glossy photographs can be used. Photostats will not be accepted. All drawings, charts, and diagrams should be prepared in waterproof India ink on high-quality paper or tracing cloth. Graph paper must not be used. No erasures should be made. Shading should be limited to a minimum and when used the lines should be kept open. The curves of graphs should be drawn much bolder than any guide lines or ruling. Lettering should be bold and sufficiently large and spaced apart so that the letters or numbers will not be less than 1 millimeter high or come in contact when reduced. Drawings should be made at least twice the size required for reproduction, and when large should be of proper proportion so that they will not exceed $4\frac{1}{4}$ by $6\frac{1}{2}$ inches (inclusive of legends) when reduced. *All explanatory matter other than the units along each axis of a graph or diagram and those designations needed for clarity should be placed in the legend.* The legend, which should be typewritten on a separate sheet, will be set in type below the figure.

Make proper reference in text to all plates, maps, and charts, and designate all of these, except tables, as figures, numbering them in consecutive order with Arabic, not Roman, numerals.

6. **Footnotes** in text should be numbered consecutively and should be placed immediately after the full line of text in which the reference mark occurs, but do not break a line of text to insert footnote. Separate the footnote from the text by two horizontal lines, one above and one below the note. In each new table footnotes should begin with 1. Do not use asterisks or other symbols to call attention to footnotes to tables.

7. **The title** of the manuscript, together with the author's name, division, or depart-

nient, and post office address, should always appear at the top of the first page of the manuscript as follows, allowing at least *triple space between lines* to permit the insertion of instructions to the printer.

TREATMENT OF DISEASES OF BROOK TROUT

JOHN EDWARD DOE

Department of Conservation, Lansing, Michigan

8. **Underscore** (italics) all scientific names of genera and species, both animals and plants, in both text and tables. Do not underscore or use all capital letters for scientific names of a category higher than the genus: *Esocidae*; *Esox lucius*. *Do not underscore any words unless italics are intended.*

9. **Inspect papers** in the last volume of the *Transactions* if you have questions concerning the arrangement of materials.

II. STYLE

10. **Bibliographic references** in text should give name of author and year of publication in one of the two following forms. "A similar reaction to light was reported by Doe (1932)." "This type of reaction appears to be common (Doe, 1932)." Do not use letters or numbers or footnotes for references. If more than one publication by the same author is given for a year, use the alphabet to designate the correct paper, thus: (Doe, 1932a) or (Doe, 1932b). In the bibliography do not repeat the author's name if reference is made to more than one of his publications, but list his publications in chronological order beginning with the earliest one. In citing a joint publication invert the name of the senior author but not of the co-author or co-authors. *Do not include any reference not mentioned in the text.* List authors in alphabetical sequence. Capitalize the first word and proper names only in the title. Follow the arrangement given below, to be placed at end of paper:

LITERATURE CITED

DOE, JOHN C., J. W. BROWN, and H. W. GREEN

1939. Treatment of diseases of brook trout. *Trans. Am. Fish. Soc.*, Vol. 68 (1938), pp. 450-461.

List only bona fide publications under Literature Cited. Do not list personal communications, typewritten reports, or processed materials given only limited distribution but rather give the appropriate citations in text footnotes at point of reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many bibliographic titles published in the *Transactions* have been found to be incomplete and inaccurate. Help us correct this situation.

11. **Tables.** Every table except leader work must have a heading and must be typewritten on a separate page. In preparing tables please make certain that they are not too large to appear on a single printed page and that the arrangement conforms with the format of the *Transactions*. *Improperly prepared tables lead to the return of many manuscripts.* Number tables consecutively with Arabic numerals (1, 2, 3, etc.). Spell all words in tables, including such words as "millimeters," "ounces," and "average" (except months *with date*, in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule.

Item	Number of fish	Percentage of total	Average length (millimeters)	Months	Cost of diet per pound
Brook trout surviving experiment No. 2	23	5.8	65	April-September	\$0.25

12. Capitals. Capitalize words when used as part of a proper name or of an identifying number or letter, or when referring to particular States, Governments, and organized bodies, or when used as proper names. For example: Lake Michigan, State of Michigan, the State, the Province, the Republic, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Hoover Dam, Pond A, State Fish Farm No. 1, Pisgah National Forest, American Fisheries Society.

Capitalize names of sections of the United States, or of any other country, as Middle West, but use lower case for a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 6.

Use lower case for scientific and common names of species. Capitalize scientific names of higher categories.

13. Abbreviations.

(a) Abbreviate the following:

Clock time, if connected with figures—2:30 a.m.

Temperatures, F. (Fahrenheit).

Degrees, whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

Number, if preceding figures—No. 125; otherwise spell out.

United States, if preceding name of a department or a bureau of a vessel, etc.—

U. S. Department of the Interior, U. S. S. *Indiana*.

Months, in body of tables and footnotes to same when followed by day of month—Apr. 5–Sept. 2 (but April–September).

(b) Do not abbreviate the following:

States, cities, etc.

Months, in text or in headings of tables—April 5–September 2.

Measures and weight, except *p.p.m.*, 6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

Percentage, 12 percent, a percentage of 25.5.

14. Numerals. Spell out *isolated* numbers less than 10, but treat alike all numbers in a series of connected groups. For example: The nets contained nine bluegills. The catch included 9 bluegills, 20 smallmouth bass, and 123 pumpkinseeds.

Use figures for enumerations of quantities and measurements, such as dimension, weight, area, volume, distance, clock time, time, money, percentage, degrees, proportion or ratios, ages, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone but use numeral if part of a hyphenated expression: one-half inch; ½-inch mesh). Examples: \$3.00 per 20 pounds; 5 feet 6 inches; 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in 1 hour and 20 minutes; 25.5 percent; 75° F.; 1:10,000; fish 2 years 6 months old; 2-year-old fish; June 29, 1936; January 1938; the 20th day of March; 1937–1938; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated. Write 50–50, not "fifty-fifty."

Do not use two figures when two numbers appear together, unless the first enu-

meration exceeds 100: ten 12-room houses; twenty 6-inch bluegills; 120 6-inch bluegills.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five lake trout," but write "Two hundred fifty rock bass and 325 lake trout were shipped."

In expressing large numbers the word *million* (or a similar larger group term) may be spelled out: 20 million, 234 billions.

15. Use of hyphen. Many compound words when used as nouns are not hyphenated but require the hyphen when used as adjectives. For example note the following sentences: "This species is adapted to *cold water*." "Ciscoes are *cold-water* fish." Write "fish culture," but "fish-culturist." Check your manuscript carefully for use of hyphen. The words, "subspecies," "upstream" and many other words originally of compound derivation are written without a hyphen.

III. SUBJECT MATTER

16. Condense your paper to the limit and omit all needless verbiage. The manuscript should be simple, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. **Papers which are too poorly written will be rejected.**

17. Be definite in reference to species. The full common name and the scientific name must be given for each species mentioned. Scientific names may be omitted from the title, if desirable, but must be given at first reference to the species in the text. Once given, scientific names need not be repeated. Follow the Society's official list of names. Do not write "smallmouth," "brook," "rainbow," etc., when you mean "smallmouth bass," "brook trout," "rainbow trout," etc.

18. Things to avoid. Words that do not appear in the dictionary in the sense employed should be avoided. The words "case," "instance," "showed," "found," "gave," and "presented," are greatly overworked in manuscripts.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: "The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass."

Avoid *split infinitives*. Please check your manuscript for this common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: "*This* was true in every case." "*The mortality* was high in every pond."

Avoid the use of a long series of nouns and adjectives as modifiers.

Avoid the use of such meaningless section headings as "Data" and "Discussion."

19. Things to remember. Well written papers are the product of careful thought and hard work. Usually they require repeated revisions that incorporate suggestions from discerning and honestly critical associates. Please make these revisions *before* submitting your manuscript.

Good writing is to a large extent a matter of good taste and good manners. Careless presentation and poor organization are rank discourtesy toward the readers.

Careless writing may save time but, once printed, a weak paper stands long as a discredit to its author.

20. Abstract of paper. Give a brief abstract at the beginning of your paper. Do not include a "Summary" at the end of your paper; if "Conclusions" are given make them brief and not a duplication of materials in the abstract.

Compiled, August, 1955

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